Metallurgical and Chemical Engineering

A Consolidation of Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. VIII. New York, May 1910 No. 5

PUBLISHED MONTHLY BY THE

Electrochemical Publishing Company

239 West 39th Street, New York.

Pittsburgh Office, 201 Oliver Building.
Western Office, Denver, Colo.
European Office, Hastings House, Norfolk St., Strand, London, Eng.

J. W. Richards, Ph.D., President.
Curtis E. Whittlesey, Treasurer. E. F. Roeber, Secretary.
Telephone Call: 4700 Bryant.

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; for all other countries, $2.50 (European exchange, 10 shillings, 10 marks, 12.50 francs).

Copyright, 1910, by the Electrochemical Publishing Company.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879

New York, May, 1910.

CONTENTS.

Editorial:
Pittsburgh and Electrochemistry 219
Oxygen and Nitric Acid from Air 219
Friedrich Kohlrausch 220
The Passing of the Argo Smelter in Denver 220
Pittsburgh's Supremacy in Iron and Steel 220
Refractory Brick 221
Bessemer Roasting 222
Pittsburgh and By-product Coking 222
Pittsburgh Meeting of the American Electrochemical Society 224
San Francisco Meeting of the American Chemical Society 225
Successor to Dr. Chandler Appointed 225
Enlargement of Ingot Iron Works 225
A New By-product Coke Oven Plant 226
The United States versus Anaconda Copper Mining Co. 226
Institute of Metals 226
Chemists' Building in New York 226
New York Section of the Society of Chemical Industry 227
News from Niagara Falls 227
The Iron and Steel Market 227
The Non-ferrous Metal Market 227
Correspondence:
Electric Steel Refining 227
Rapid Electric-Analysis with Stationary Electrodes. By Allen P. Ford 229
Efficiency of Dryers. By W. E. Wadman and W. B. Ruggles 229
The New Blast Furnace of the Bethlehem Steel Co. By W. S. Landis 231
The Electric Furnace in Non-Ferrous Metallurgy. By Jos. W. Richards 233
Commercial Oxygen. By E. A. LeSueur 234
Defects in Refractory Brick and Their Causes. By Gilbert Rigg 237
Furnace Electrode Losses. By C. Hering and A. E. Kennelly 238
Chemical Reactions at Electrodes. By Reston Stevenson 240
Can National Professional Societies Be Exclusive and Representative? 244
The Electrical Testing Laboratories and Electrochemistry. By Clayton H. Sharp 245
Causes of Non-Uniformity of Blast Furnace Operation. By Edward B. Cook 251
Metallic Sodium from Fused Sodium Chloride. By C. F. Carrier 253
Temperature Coefficients of Resistance of Resistors 257
Silica Standards of Length 257
High-Temperature Gas-Thermometry and Its Present Limitations. By Arthur L. Day 257
Smelting of Fine Ore and a Sintering Machine. By A. B. Young 260
The Attainment of Highest-Purity Iron on a Commercial Basis. By James A. Aupperle 262
The Chemist in the Brass Foundry. By W. M. Corse 265
Concentration of Sulphuric Acid 266
The Chemical Industries of America. By Charles E. Munroe 267
The Tube-Mill Circuit and Classification. By G. O. Smart 271
Modern Electroplating Plant 274
Improving the Output and Efficiency of Existing Electric Furnaces. By Carl Hering 276
Electric Smelting of Nickel Ore 277
On the Equilibrium of the System Consisting of Lime, Carbon, Calcium Carbide, and Carbon Monoxide. By M. deKay Thompson 279
Notes on Chemistry and Metallurgy in Great Britain 282
Synopsis of Metallurgical and Chemical Literature 284
Recent Metallurgical and Chemical Patents 288
Aquadag as a Lubricant 293
A New Hot-Blast Stove 294
Electrostatic Ore Separation 295
Generators for Electrometallurgical Work. By M. Berthold 296
System for Utilizing the Heat of Blast-Furnace Slag 297
Repairs of Broken Castings by Reinforced Brazing. W. G. Swaney 300
Ozone Apparatus 301
Acid-Proof Stoneware Tank 301
Voltage Control of Transformers for Electric Furnaces 303
A Scientific Abrasive 304
Notes, Personal Digest, Book Notes 304

Pittsburgh and Electrochemistry.

Electrochemical engineering is not a strange or new art in Pittsburgh. On the contrary, the early history of electrochemical industries in this country—Hall's work on aluminium and Acheson's work on carborundum—is intimately connected with the Pittsburgh district. Only after these two pioneer electrochemical industries had been there founded on a commercial scale were they transplanted to the new power center, Niagara Falls, which then grew into the electrochemical center par excellence. Now, however, with electric steel refining furnaces increasing almost daily in importance, it requires no particular flight of fancy to think of Pittsburgh as another coming electrochemical center. But how different such a statement sounds now from what it would have sounded a few years ago. Then iron men would have thought of the electric furnace trying to replace the blast furnace. Now it is universally understood that the big field of the electric furnace in iron and steel metallurgy is as an adjunct to the Bessemer converter and to the open hearth to produce that better steel so urgently needed.

* * *

The American Electrochemical Society has wisely selected Pittsburgh for the place of its annual meeting in May. It can no longer be said that the society enters thereby the enemy's country. Progressive steel men now recognize the helper and friend in the electric furnace man. To reach a perfect mutual understanding of all the various phases of the problem, nothing can be more effective than social intercourse and heart-to-heart talk between both classes of engineers, and for this the convention will offer abundant opportunities. So we look forward expectantly to one of the most successful and pleasant meetings, especially since electrochemists are now returning for the first time as a professional body to the place of their early triumphs. On revient toujours à ses premiers amours.

Oxygen and Nitric Acid from Air.

Mr. Ernest A. LeSueur, who 20 years ago was the pioneer of the diaphragm cell for sodium chloride electrolysis, has contributed to this issue a most interesting article on "commercial oxygen," produced from the atmosphere by a simple mechanical process. The subject attracts just now great attention. If it would be possible to produce "commercial oxygen" cheaply enough, many applications of it in large-scale metallurgical and chemical engineering processes could be worked out. As Mr. LeSueur points out, to be cheap the method should be a mechanical or physical rather than a chemical one; further, it should not be necessary to produce pure oxygen. If an atmosphere enriched in oxygen compared with the ordinary atmosphere is sufficient, he claims it can be produced at a very reasonable figure by a sort of turbine or "steam engine."

* * *

In this connection attention may be called to an abstract of a patent of Mr. Henry Howard, also given in this issue, for the continuous production of nitric acid from air. In a very clever

way the machinery is so designed as to fulfill the desiderata of that theory according to which the oxidation of the nitrogen is a purely thermal phenomenon. First, compression, and, by electric discharges, establishment of a gas mixture comparatively rich in nitrogen oxides, and then an exceedingly quick cooling of the mixture so as to "freeze" the equilibrium corresponding to the higher temperature and prevent the dissociation of the nitrogen oxide. This cooling effect is obtained by sudden expansion of the gas mixture while performing work in an engine or turbine. Mr. LeSueur's article and Mr. Howard's patent are interesting examples of the novel application of mechanical engineering principles in chemistry.

Friedrich Kohlrausch.

In Friedrich Kohlrausch, Germany has lost one of its most prominent and influential physicists, a past-president of the Physikalisch-Technische Reichsanstalt and the one man who has done more than anyone else to cultivate experimental laboratory work in physics in German universities. As to his research work along manifold lines, attention may be called here only to his very extended and minutely accurate investigation of the electric conductivity of salt solutions at varying concentrations, which, taken together with Hittorf's determination of transference numbers, enabled him to establish the law of the "independent migration of ions" for infinitely dilute solutions. Qualitatively at least, this was the first statement of the electrolytic dissociation theory. What has been added later is Arrhenius' method of determining by different methods the degree of dissociation in solutions which are not infinitely dilute and the great generalization of the theory by numerous investigators whereby it became possible to apply it to many problems of the theory of solutions and of general chemistry.

The Passing of the Argo Smelter in Denver.

The last days of March witnessed the drawing of the fires from the furnaces at the smelting plant of the Boston & Colorado Smelting Company at Denver. The Argo smelter, as the plant was commonly known, has been one of the most interesting and important factors in Western metallurgy for almost 40 years. Originally established at Black Hawk, 30 miles from Denver, at a time when the rich surface free-milling ores of that famous camp had given place to sulphides, the Argo smelter played a leading part in the fortunes of the miners who were discouraged over their rapidly diminishing gold recoveries from ore known to contain high values. The leading spirit in establishing the smelter was Nathaniel P. Hill, at that time a young Eastern college professor. The process used resulted in the production of a rich copper matte which was shipped to Swansea for refining. Later Mr. Richard Pearce introduced the Ziervogel process for recovering the silver, and introduced a method for treating the residues for gold which was kept secret for almost 40 years. When finally disclosed it was found to be simple, and a number of metallurgists confessed to having guessed the principles involved some years before their disclosure. The gold was concentrated in copper bottoms which were subsequently granulated and smelted in a reverberatory furnace with iron pyrites. Successive meltings and granulations with final treatment in the refinery in crucibles yielded a bullion 920 fine in gold.

This system of smelting and refining, using copper as a base, was continued to the end, although lead smelting developed far beyond the possibilities of copper smelting in Colorado. In 1906 the Argo refinery was destroyed by fire and since that time the matte has been sold to the American Smelting & Refining Company. The diminishing fortunes of the Argo plant were coincident with the discovery of rich lead ores and the genesis of lead smelting in Colorado. Copper ores have never been abundant in that State, and it has always been possible to handle them in lead smelting plants, producing a low-grade matte which was subsequently concentrated to a grade suitable for refining in the converter. The Argo company at one time established a second plant at Alma, Col., but it was not profitably operated and was finally abandoned. It is an interesting speculation to consider what would have been the effect on the lead smelting industry of the West had the Argo company entered the lead smelting field instead of sticking to its own process, which finally became antiquated. The ingenuity of its metallurgists and the prestige of its financial backers should have made it a formidable factor in present-day developments. The history of the company shows it to have been very successful, and it retires with the good will of many miners who had dealings with it.

Pittsburg's Supremacy in Iron and Steel.

It is only among those who are unaccustomed to think in quantities that the notion has been entertained that Pittsburg loses any material part of her prestige as an iron and steel producing center by the building of the steel plant at Gary, Ind. The Gary plant exemplifies an important economic principle, but by no means a new one. Nearly 20 years ago it was common talk in the industry that a location on the Great Lakes had an advantage over the remainder of the Central West, because it was better for the fuel to go to the ore than the ore to the fuel, but instead of a general oxodus only a few stragglers have wended their way to a lake site. The Johnson Company moved from Johnstown, Pa., to Lorain, Ohio, making its first steel at the new site April 1, 1895, but owing to financial stress did not obtain the real benefit of the lake site for more than four years, since it was not until July 5, 1899, that the company made pig iron at Lorain. A few years later the Lackawanna Iron & Steel Company packed up its goods at Scranton, Pa., and moved to Buffalo. The Gary plant, at the south end of Lake Michigan, is, of course, different in that it does not in any sense represent a removal, for the United States Steel Corporation has clearly had no intention of moving any equipment or transferring any trade. The Gary plant is built from the ground up, with fresh capital, and its object is to take care of the increased requirements of the Western market.

* * *

The Gary plans, as outlined in the steel corporation's report for 1907, comprised eight blast furnaces and 56 60-ton open hearth furnaces, the blast furnaces being rated at 450 tons per day each, and the 56 open-hearth furnaces at 225,000 tons of ingots per month. This much was authorized at the time, and the statement was further made that an increase in the blast furnaces to 16 was ultimately contemplated, with a corresponding increase in the open-hearth and other equipment. In either case there would have been a large preponderance of steel mak-

ing over blast-furnace capacity. Apparently the plans have since been modified, for the present status of the work is that of eight blast furnaces completed, with six in blast and 28 open-hearth furnaces completed and in operation, with 14 to be completed this summer, eight blast furnaces and 42 open-hearth furnaces being expected to balance. It does not seem probable that the project will be expanded beyond these limits for some time. The function of Gary is to make steel by the most modern and approved methods, rather than to make an enormously large tonnage. The eight furnaces may be rated at 1,200,000 tons of pig iron annually, the steel ingot production being larger, through the reuse of scrap, while the finished steel output will doubtless be approximately commensurate with the pig iron tonnage.

* * *

From a tonnage standpoint, Pittsburg need not consider such an operation as presenting serious rivalry. One can arrive at Pittsburg's tonnage potentialities better by a study of what has been accomplished than by a mere survey of rated capacities. To do this it is necessary to go back to 1906, the last year of full employment, and then allow for new construction since that time. This, by the way, will show quite forcibly that Pittsburg has not stopped growing. Statistics of the production of Allegheny County, of which Pittsburg is the county seat, are given for 1906 as follows by the American Iron & Steel Association:

	Gross tons.
Pig iron	5,702,721
Bessemer steel	3,255,064
Open-hearth steel	3,799,907
Other steel	50,530
All steel	7,105,501
Rails	851,419
Structural shapes	1,054,747
Plates and sheets	1,300 873
All rolled products	5,686,017

The Mahoning and Shenango valleys, midway between Pittsburg and Lake Erie, and the Wheeling district, as well as various scattered plants in Western Pennsylvania, might perhaps be included with Pittsburg, but drawing a strict line we include with Allegheny County only a few plants just outside the county and distant less than 30 miles as the crow flies from the heart of Pittsburg. Thus we add to the above tonnage an allowance for the Midland and the two Donora furnaces, about 450,000 tons of pig iron annually. Since 1906 there have been built and put in operation within this circumscribed district: In 1907, two Carrie and one McKeesport furnaces; in 1909, two Dusquesne and one Aliquippa; in 1910, two Aliquippa, these eight furnaces having a rated capacity of 1,370,000 tons a year. Altogether, then, the present pig iron capacity of the immediate Pittsburg district is fully 7,500,000 tons a year, more than six times the prospective capacity of the Gary plant as at present outlined.

* * *

In steel capacity there is an increase since 1906. The Bessemer department at Duquesne, two 10-ton vessels, has been dismantled, but in place are 18 open-hearth furnaces with greater capacity; at Homestead there is additional open-hearth capacity, and at Aliquippa the Jones & Laughlin Steel Company is completing four 200-ton Talbot furnaces. With minor improvements at other plants, and considering the steel capacity at Vandergrift, Butler and Donora, just outside the county, the prospective steel ingot capacity is well in excess of 8,000,000 tons annually. With 7,500,000 tons of pig iron capacity, the Pittsburg district makes only about a quarter-million tons of merchant pig iron a year. It is not a center for the manufacture of the finer products of the foundry, nor, indeed, does it surpass other districts so much in the finer forms of steel as it does in tonnage. There is room for Pittsburg to grow along these lines, as the necessity is reduced for it to grow in the production of the heavy forms of steel.

Refractory Brick.

The subject of refractories is of immense importance for metallurgical and chemical works. But the knowledge of this subject is scattered and illusive or at least indefinite. By their contact with the whole of chemical and metallurgical industries the makers of firebrick have acquired some practical data of undoubted general value on the relation between methods of manufacture and properties of firebrick, while chemists and metallurgists in special fields have valuable and definite ideas on what kind of special refractories they want or need. But the trouble seems to be that there is not yet the right co-operation or understanding between the manufacturer and consumer of refractory brick. That a refractory brick may be excellent for one purpose and wholly unsatisfactory for another goes without saying. An acid brick is destroyed by a basic charge or slag. But besides the chemical nature of the reaction, the purely physical factors are of equal importance. The consumer should know the maximum temperature which his brick has to stand, and the firebrick manufacturer should adjust his baking process accordingly so as to produce a brick that will not shrink at the highest temperature in use. To indicate how contradictory the requirements are in different cases, we may simply mention that in most cases firebrick is expected to be a poor heat conductor in order to reduce the heat loss, while in other cases—in zinc retorts, in muffle roasting, crucible melting, etc.—the refractory is expected to transport the heat from the outside to the inside with high efficiency. It seems that a discussion of the subject of refractories from the standpoint of both the consumer and producer should do much good for both parties concerned. It is with pleasure that we call attention to an interesting article on defects in refractory brick and their causes, contributed to this issue by Mr. Gilbert Rigg, in charge of the experimental work of the New Jersey Zinc Company. It is the result of a large number of studies and tests and is contributed in the hope of starting a discussion on this subject. For this purpose and in the hope of doing something useful we place our columns gladly at the disposal of both users and makers of refractory brick.

Irregularities of Blast-Furnace Running.

Our January issue contained an article on regularity of blast-furnace operation, by Dr. Joseph W. Richards, and in the present issue will be found an article, more or less supplementary to the former one, on the chief irregularities of blast-furnace running by Mr. Edward R. Cook, of the Warwick Iron Company, written from the blast-furnace manager's standpoint.

That these two authorities should agree on the main points under discussion is highly satisfactory from the standpoint of blast-furnace literature; that they should lay the chief emphasis on different phases of the problem is perfectly natural and no less instructive than their points of agreement. In brief, Dr. Richards assumes a furnace in good running order, not near the close of a campaign, and discusses the factors of regularity in its running such as are concerned with its immediate management and treatment. On the other hand, Mr. Cook starts with the tacit assumption that all these factors are inferior in importance to combating those secular changes which mark declines in output steadily operating through months of running and which finally compel the furnace to go "out of blast." Mr. Cook very aptly says: "Take a blast furnace built on proper lines and anybody can run it; take one built improperly and no one can run it." Dr. Richards' discussion applies, therefore, to the best and most regular running of a furnace assumed to be built properly; Mr. Cook's mainly to the irregularities and difficulties met in a furnace built improperly, causing secular changes which finally stop the furnace.

* * *

Both discussions are, therefore, valuable, and we do not hesitate to designate Mr. Cook's as the more fundamental, because it is certainly imperative to have, first, a furnace capable of being kept "in blast" before it becomes worth while to discuss how to run it most regularly and most efficiently. Mr. Cook has discussed the great fundamental difficulty of keeping the blast furnace in operation; Dr. Richards the fine points and finishing touches, or refinements concerned in its steady operation at highest efficiency. Some of Mr. Cook's statements will hardly pass the scrutiny of the blast-furnace profession unchallenged. The statement that no one knows how to build the blast furnace right should provoke discussion. His statement that the three largest producing blast furnaces in the United States, in 1909, were three dry-blast furnaces, certainly proves the very great importance and value of the items of regularity discussed by Dr. Richards. In fact, we cannot but regard the questions raised as "open" questions, and their further discussion by technicians and theorists is likely to prove profitable all around.

Bessemer Roasting.

Evolution of technical terms is coincident with the changes in practice, and final usage is usually dictated only by a full understanding of the principles of a method or process. As long as the latter is in a transitional stage, the descriptive terms used are likely to be numerous, local in their origin and meaning, and not wholly satisfactory. The developments of the past few years in the practice of roasting sulphide ores have given rise to a number of terms, no one of which seems wholly adequate to express concisely the principles involved and the result obtained. Various terms such as sintering, pot roasting, layer roasting, blast roasting, lime roasting, etc., have been proposed and used. An analysis of these terms will show that each of them has some special significance, referring to the mechanical device used, the nature of the mixture to be roasted, or the general result obtained, but none of them can be considered a generic term complying with the conditions mentioned, so that it is worth while to look for a better one.

A recent metallurgical writer has suggested the use of the term "Bessemer roasting," as fulfilling all the conditions. The Bessemer process implies the use of a blast of air to effect certain chemical changes without the use of extraneous fuel. In steel making the Bessemer process is based upon the heat evolved by the oxidation of certain elements in pig iron. In "Bessemerizing" copper matte we have similar conditions and results, applying a blast of air to oxidize sulphur and iron and to liberate copper. Finally the analogy is apparent in what it is proposed to call Bessemer roasting, for in that process we resort to a blast of air to oxidize the sulphur, and the process is carried on with the fuel contained in the ore itself. The suggested term is properly descriptive from a metallurgical point of view. It is independent of the details of the mechanical application of the process, which, indeed, are the most unsettled features of it. Roasting in pots was an early application, and only a short time ago it appeared that roasting in thin layers would supersede the pot process, but that has not yet come to pass. The term "lime roasting" is no longer tenable, since it lays stress on a feature now known to be unessential. Finally, sintering can be accomplished in a variety of ways and furnaces, and the term has no reference to the Bessemer feature of the roasting process as now carried out. On the whole it seems as though the term "Bessemer roasting" is the most acceptable that has been proposed, and we are glad to endorse it and bespeak for it general usage.

Pittsburgh and By-Product Coking.

It would appear that the iron and steel industry has experienced sufficient expansion in tonnage capacity to cover the requirements of the market for a time and is destined to devote its energies chiefly to the introduction of economies and improvement of product. In the last dozen years three periods of high pressure have alternated with periods of depression. The spectacular boom of 1899 was followed by a sharp and short readjustment in 1900; the next period of high pressure lasted longer, and was followed by the depression extending from late in 1903 to late in 1904, this giving way to three years of high pressure followed by a depression of a year and a half. Each period of high pressure caused plans to be adopted for new erection, much of the new capacity not becoming effective until the pressure for material had subsided. The next period of high pressure would show the new capacity to be needed, and would give rise to a fresh burst of new erection. The longer the period of high pressure, the greater the amount of new erection undertaken, and thus it came about that in the most recent period of high pressure the crop of new blast furnaces and steel works was by far the largest of all. The depression is past, the new erection is not all completed, yet existing capacity is not fully engaged. In other revivals it required but a few months to take up all the slack and produce a position in which mills were falling farther and farther behind in their deliveries.

* * *

The iron and steel industry is always improving its methods and appliances, but the rate of progress varies from time to time. We do not assert that if it were possible to list all the improvements made in the past quarter century it would not be found that more improvements were introduced in periods of extreme prosperity than in periods of relative depression, but

if so the showing would be made so by there being much more new erection in periods of prosperity than in periods of adversity. Relative to the amount of money spent, the greatest progress is undoubtedly made when profits are small. Nothing could be more natural. When existing capacity is taxed and producers are falling behind in deliveries it is justifiable in new erection to build as others have built before; when existing capacity is not fully engaged it is necessary to justify the new erection by improvements over existing practice. In these circumstances the next few years in the iron and steel industry promise to constitute a period of improvement in methods and appliances. Along these lines by-product coking looms large. In our March number we pointed out that the development of the large gas engine greatly increased the feasibility of by-product coking by furnishing a new and unlimited field of usefulness for the gas, and we do not wish here to traverse any of that ground again. Rather, we take as our theme the Pittsburgh district as a locus for by-product coking. The suggestion as to the unwisdom of "carrying coals to New Castle" may arise in the minds of some of our readers, but let us look into the matter a little. The Pittsburgh district is one of the greatest consumers of power in the world, and most naturally, for once Pittsburgh was only the junction of two rivers surrounded by forests and the industries were attracted chiefly by cheap fuel; naturally they were industries which require a great deal of it. Pittsburgh was the home of aluminium manufacture until the Niagara Falls power became available.

* * *

Pittsburgh, it may be said, is a natural gas center; hence, why try to make there the much poorer gas which by-product coking yields? Let us see. From a natural gas standpoint the State of Pennsylvania is practically the Pittsburgh district. The Geological Survey reports show a rapid increase in Pennsylvania's natural gas production, until 1904, since which year the value has been almost stationary, and we know perfectly well that the quantity must therefore have been decreasing, since values per 1000 ft. have been steadily increasing. Statistics of quantity are available only for 1907 and 1908. They are as follows for Pennsylvania, in thousands of cubic feet:

	1907.	1908.
Production	135,516,015	130,476,237
Consumption	164,541,179	147,790,097

The decreased consumption in 1908 was, of course, due to the industrial depression. Pennsylvania, as a matter of fact, imports a great deal of natural gas from West Virginia, and is destined to import more and more, if no substitute is found. Fortunately for our purpose, the Geological Survey has divided the consumption for domestic and industrial purposes, and in view of the industrial depression we cite only the figures for 1907 as follows:

	1000 cu. ft.	Value—Cents per 1000 cu. ft.
Domestic	44,840,748	24.2
Industrial	119,700,431	10.1

Inasmuch as the domestic consumption in Pittsburgh is steadily increasing and as West Virginia gas can be piped to many towns for domestic consumption, it would be absurd to expect that the gas would continually be sold for industrial purposes when it will bring more than twice as much if sold for domestic consumption. Indeed, a large part of the gas used for industrial purposes is produced by the manufacturers, who are not in the business of distributing for domestic consumption. Year by year the cost of finding and developing new wells increases, so that the use of natural gas for industrial purposes in the Pittsburgh district is necessarily decadent.

* * *

An oblique view is frequently taken of the hardiness, both of Connellsville coking coal and of Lake Superior iron ore. In both cases the reputation of the region was made by the best of the deposits, but in summaries of the "life" of the region the conception seems to be the product of the quality of the best by the quantity of the total. Much of the best Connellsville coking coal is gone, just as much of the best Lake Superior ore is gone. Pittsburgh industries can use an almost unlimited amount of by-product gas, and the coke requirements are equally large. Connellsville coke takes a freight rate to Pittsburgh of no less than 75 cents per ton of 2000 lb. for a haul perhaps averaging 50 miles. When blast furnaces were put in operation at Aliquippa only 20.5 miles below Pittsburgh, a rate of 99 cents was made on Connellsville coke, 24 cents being added for 20.5 miles additional haul. There is coal everywhere about Pittsburgh, most of it adapted to by-product coking, and in many cases there need be no freight charge at all. In other cases the rate would be very low, compared with the preposterous rate on Connellsville coke. There would even be an advantage in making by-product coke at Pittsburgh for consumption elsewhere, since Pittsburgh could use the gas and allow the coke to go. In cases in which the coal had to be transported to the by-product ovens a low freight rate could undoubtedly be obtained, on the principle well recognized by the railroads of permitting manufacture in transit. Observing this principle, the railroads are at the present time making very low rates on Connellsville coal shipped for coking to beehive ovens whose coal seams are worked out.

* * *

While the railroads maintain very high rates on Connellsville coke, they could be counted upon to make the lowest possible rates in connection with the establishment of by-product ovens, for the railroads are committed to the fostering of this industry in order to increase the supply of creosote obtained from coal, since they need the material for tie preservation and expect to require very large quantities. In the report of the special committee on "Conservation" presented to the annual meeting at Chicago, last March, of the American Railway Engineering and Maintenance of Way Association, one of the recommendations was: "That efforts be made to secure such improvements and economies in the construction and operation of by-product coke ovens as will lead to their general substitution for the beehive type." The immediate Pittsburgh district promises to consume regularly approximately 8,000,000 tons of coke, chiefly in blast furnaces. Surely there is reason to expect that ultimately most of the coke will be made in by-product ovens, the gas being used for various industrial purposes. Of course, the blast furnace is itself a gas producer and it is claimed that blast-furnace gas is sufficient to furnish all the power necessary to finish steel in the heavier rolled forms. There remains, however, the heating of the steel and as electric steel refining grows, employment will be furnished for all the gas from both coke oven and blast furnace.

Pittsburgh Meeting of the American Electrochemical Society.

The seventeenth general meeting of the American Electrochemical Society will be held in Pittsburgh from May 4 to 7 (that is, Wednesday to Saturday of the first week in May). Hotel headquarters will be at the Fort Pitt Hotel, quite near the Union Station. The registration of members and guests will begin at the Fort Pitt Hotel after 12 m. Wednesday, May 4. Tickets for the all-day Friday excursion and the Friday evening dinner should be obtained from the registrar when registering.

The program is as follows:

Wednesday afternoon, May 4. A visit, starting from the Fort Pitt Hotel, at 1:30 p. m., will be made to the technological testing plant of the U. S. Geological Survey. This is perhaps the largest Government testing plant in the world and its inspection will be of the highest interest to the scientific technologist, especially as the management is arranging special tests and exhibitions of particular interest to the visitors.

In the evening at 8:30 p. m. there will be an informal reception in the English Room of the Fort Pitt Hotel by the officers of the society and the local committee to the visiting members, ladies and guests.

Thursday morning, May 5. The annual business meeting of the society will be held at 10 a. m. in the Convention Hall of the Fort Pitt Hotel, where the result of the annual election of officers will be announced and the report of the board of directors will be presented.

This is to be followed by a professional session at which the following papers will be read and discussed:

Determination of the constants of materials for furnace electrodes. By Carl Hering.

Empirical laws of furnace electrodes. By Carl Hering.

On Hering's alleged laws of electrode losses in electric furnaces. By C. J. Reed.

A study in furnace conductors for heavy alternating currents. By K. C. Randall.

A new electric steel furnace. By A. L. Queneau.

On the presence and influence of gases in steel. By P. L. T. Héroult.

Thursday afternoon, May 5. Excursions and visits to the following plants have been arranged for the afternoon, all proceeding from the Fort Pitt Hotel, after lunch, each under the direction of one or more guides familiar with the plants to be visited.

Pennsylvania Smelting Company, Carnegie, Pa. (Smelting of lead-silver ores in blast-furnace, refining and desilverizing base bullion, cupellation of silver, etc.)

Park Steel Works of Crucible Steel Company of America. (Puddling furnaces producing muck-bar, open-hearth furnaces producing basic open-hearth steel, crucible furnaces producing high-grade tool steels.)

Jones & Laughlin Steel Company. (Bessemer steel process, basic open-hearth process, Talbot continuous process in tilting furnaces. Rolling of merchant bars, structural shapes, plates, sheet bars, cold-rolled shafting, etc.)

Isabella Furnaces of Carnegie Steel Company, Sharpsburg. (Modern iron blast furnaces equipped with Gayley's original plant for drying the blast.)

Universal Cement Works. (Manufacture of cement from granulated blast-furnace slag.)

Pittsburgh Reinforced Brazing & Machine Company. (Brazing and repairing broken castings by special methods. Oxy-acetylene welding of heavy and light work.)

Nernst Lamp Company. (Manufacture of commercial Nernst lamps.)

Thursday evening, 8 o'clock. A session will be held in the Convention Hall of the Fort Pitt Hotel.

The retiring president, Dr. L. H. Baekeland, will deliver his presidential address on "Science and Industry," whereupon the following papers will be read and discussed:

Possibilities of cheap power in the Pittsburgh district. By F. Crabtree.

Induction furnace progress. By T. Rowlands.

Ductile tungsten and molybdenum. By C. C. Fink.

A new process for the treating of cobalt-nickel ores rich in silver and arsenic, by combined melting and electrolytic operation. By C. C. Cito.

Evolution and present status of the dry cell. By D. L. Ordway.

A new radiation pyrometer. By C. E. Foster.

Friday, May 6. All-day excursion, leaving Union Station at 8:20 a. m. on special train. Lunch will be served on the train, and the following plants visited in the order given, returning to Pittsburgh about 5:30 p. m.:

Allegheny Plate Glass Works, Glassmere.

Westinghouse Electric Works, East Pittsburgh.

Westinghouse Machine Works, East Pittsburgh.

Firth-Stirling Works, Demmler (Héroult electric steel furnace in operation).

Carnegie Steel Works, Homestead.

Tickets for the excursion may be obtained from the registrar at a cost of $1.50.

Friday evening, at 7 o'clock, an informal subscription dinner will be held at the Fort Pitt Hotel. Ladies are particularly invited.

Saturday morning, May 7, 9 o'clock, a professional session will be held in the Engineering Building of the University of Pittsburgh. The following papers will be read and discussed:

On the separation of oil from condenser water by electrolysis. By H. M. Goodwin.

A new method for electrolytic winning and refining of metals. By E. M. Chance.

An electrolytic method for the reduction of casiterite. By W. O. Snelling.

Refining of tin dross in an electric furnace. By R. S. Wile.

The conductivity and electrolysis of cuprous chloride solutions. By M. deKay Thompson.

The electrolytic reduction of nitric acid (third paper). By H. E. Patten and W. J. McCaughey.

The effect of moisture and of solutions upon the electrical conductivity of soils. By R. E. O. Davis.

The electrochemical potentials of calcium-aluminium alloys. By Jas. Breckenridge.

A rotating graphite anode. By J. W. Turrentine.

Comparison of rapid electrochemical methods. Part I.—The Determination of Copper. By F. C. Frary and A. B. Peterson.

The electrolytic deposition of platinum—II. By Wm. J. McCaughey and H. E. Patten.

The use of perchloric acid in metal-plating baths. By C. F. Mathers.

The Whiting electrolytic cell for the production of caustic alkali and chlorine. By Jasper Whiting.

The Townsend cell; its behavior under various current densities. By H. K. Richardson and R. L. Patterson.

Lunch will be taken in the Hotel Schenley.

Saturday afternoon, 2:30, a general public meeting will be held in Carnegie Music Hall, when an illustrated address on the present status of the electrochemical industries will be delivered by Dr. J. W. Richards, secretary of the American Electrochemical Society.

This will be followed by Dr. John A. Brashear on the advantages of Pittsburgh as an electrochemical center.

Finally, an address on the conservation and utilization of natural sources of power will be made by Mr. John H. Finney.

This meeting may be conveniently followed by visits to the Carnegie Institution and Museum, Carnegie Technical Schools,

University of Pittsburgh, and other points of interest in the vicinity.

For the evening arrangements will be made for a social gathering of members and guests who do not leave by the early evening trains.

A ladies' committee will take care of the entertainment of visiting ladies. Ladies are invited to attend the session of the society on Thursday morning and evening and Saturday morning, and are specially invited to the general public meeting in Carnegie Music Hall on Saturday afternoon. Ladies are also invited to attend the visit to the U. S. Testing Plant on Wednesday afternoon and any of the visits scheduled for Thursday afternoon.

Ladies are particularly invited to be present at the informal reception on Wednesday evening, at the informal dinner on Friday evening and also to the lunch at Saturday noon.

Ladies are not invited to accompany the all-day excursion on Friday; on this day the Ladies' Committee will provide a pleasurable program consisting of automobile rides, visits to art galleries, lunch, etc.

San Francisco Meeting of the American Chemical Society.

The summer meeting of the American Chemical Society, to be held in San Francisco from July 12 to 15, 1910, promises to be one of the pleasantest outings ever enjoyed by the members of the society.

A special train made up of the Santa Fé's finest equipment will leave Chicago on the evening of July 4, arriving at Colorado Springs on the morning of July 6. About six hours will be allowed for a trip to Manitou, the Garden of the Gods or to the top of Pike's Peak. Leaving about 1 o'clock the train will reach Adamana on July 7 and a half day will be spent in a visit to the Petrified Forests, two of which and possibly three may be examined. Leaving Adamana that night the party will arrive at the Grand Canyon of the Colorado on the morning of July 8, where the day will be spent. Leaving the Grand Canyon that evening the train will arrive at Redlands and Riverside, Cal., the following afternoon and about two hours and a half will be given to the semi-tropical scenery of each of these two cities.

Sunday, July 10, will be spent at Los Angeles, leaving there in the evening and arriving at Lang, Cal., on the following morning. At Lang the borax mines will be visited on invitation of Mr. S. T. Mather, of the Thorkildsen-Mather Company, where the party will be their guests until about 1:30 o'clock, when the train will leave for Santa Barbara, giving us about five hours in that unequalled seaside resort. During the night the train will leave for San Francisco via the coast route of the Southern Pacific, probably reaching our destination about 12 o'clock of the 12th.

The meeting will follow and entertainment by the California Section. The tentative program for the entertainment includes: First, a steamer trip around the bay and out through the Golden Gate; second, a trip to the top of Mt. Tamalpias and to the Muir Woods, the first giving an extensive view of the ocean, the bay and the surrounding mountains and hills, while the second contains fine specimens of the coast redwood (*sequoia sempervirons*); third, an excursion on the Ocean Shore Railway to Pescadero with a possible return via the Santa Clara Valley; fourth, an excursion to the vineyards and wineries of the Italian-Swiss colonies in Sonoma County; fifth, a visit to the University of California at Berkeley; sixth, a visit to Stanford University with a possible automobile trip through the orchards of the Santa Clara Valley; seventh, a camping-out trip for one night and parts of two days into the Big Basin, the State Park, where some of the biggest redwoods are to be seen; also it is hoped to visit some of the local manufacturing plants.

Following the meeting the party will dissolve as a whole, returning as they desire, either via the smelters in Utah and Colorado, via the beautiful scenery of the Canadian Pacific, or via the National Yellowstone Park.

Unusually low rates have been obtained from Chicago; namely, $62.50 for the round trip from that city with $15 extra if the party returns via the northern routes. There will be $6.50 extra railway fare on the side trip to the Grand Canyon. The berth rate from Chicago to San Francisco will be $14, with an additional charge for the four extra days in transit in lieu of hotel expenses, as the Pullmans will be used throughout the trip. This additional charge will approximate $7 on the berth rate.

The Puget Sound Section are hoping that a considerable number of the members may decide to return via Seattle.

In view of the efforts that are being made by the California members and of the unusual attractions of the trip, it is hoped that a special effort will be made by Eastern members to be present at the meeting. Reservations for the special train will be made in the order of their receipt. Any members of allied societies going West at this time who may wish to share in the privileges of the special train should address the secretary, Dr. Charles L. Parsons, New Hampshire College, Durham, N. H.

Successor to Dr. Chandler Appointed.

The trustees of Columbia University have announced important changes in the department of chemistry made necessary by the announced retirement of Prof. Charles F. Chandler. The administrative duties of the department will be assumed by Dr. Marston T. Bogert and a new chair of industrial chemistry has been created to be filled by Mr. Milton C. Whitaker. Dr. Bogert, a past-president of the American Chemical Society, has been associated with Dr. Chandler as professor of organic chemistry, and will now be administrative head of the department. Mr. Whitaker has been superintendent of the Welsbach Company's works at Gloucester, N. J. In 1897 he graduated from the University of Colorado and entered Columbia University as a graduate student, where he engaged in research work in the department of chemistry until 1902, when he entered the employ of the Welsbach Company. Mr. Whitaker's work in the department will begin next school year. The trustees also announce the acceptance of the fund raised by the alumni of the University to establish a lectureship in honor of Dr. Chandler.

Enlargement of Ingot Iron Works.

Elsewhere in this issue will be found an article by Mr. James A. Aupperle, chief engineer of the American Rolling Mill Company, of Middletown, Ohio, on their American ingot iron. In this connection the following notes on considerable enlargements of the works of this company should be of interest.

The American Rolling Mill Company is erecting a new plant at Middletown, Ohio, the cost of which when completed is estimated at $3,300,000. It is on a lot of 475 acres, one mile east of the present 50-acre plant, and connected by private right-of-war. The P. R. R., Big Four, and C. H. & D. offer excellent shipping facilities.

The work being done at present is largely grading, and a couple of steam shovels are busily engaged making the change of some seven feet, which is the average for the entire plot.

One of the unusual features of the new plant is the elimination of the narrow-gauge "dinkey" service. All trackages throughout will be of standard gauge.

The plans of the proposed equipment call for four 65-ton, open-hearth furnaces; one, 40" blooming mill; one 24" billet mill; two jobbing mills; eight sheet mills, together with a complete cold rolling department for the manufacture of uniform color sheets. For the galvanized sheets, eight pots will be provided, the hot process, of course, being employed.

At present the company buys pig iron, but the ultimate plan calls for the erection of blast furnaces to furnish all necessary stock.

The entire new plant, with the exception of the blooming and billet mills, will be electrically driven, and Westinghouse apparatus is to be installed throughout.

Three turbo-generators, each of 2150 kilovolt-ampere capacity (1500 kilowatts at 70 per cent. power factor), will furnish the power. The turbines are high-pressure and low-pressure, the former taking steam direct from the boiler plant and the latter using the exhaust from the engines on the blooming and billet mills. In case of shortage in the latter, automatic interconnection of the units permits the admission of live steam direct to the low-pressure turbine. This device also gives a very great overload capacity. The low-pressure turbine installation offers obvious advantages, as the power for the largest rolling mill engines can be obtained at a very high total thermal efficiency.

The sheet and jobbing mills are to be driven, respectively, by one 1500-hp and one 1000-hp alternating-current motor, each operated at 2200 volts and 25 cycles, the current coming direct from the alternators.

The cranes and tables will all be operated by direct current, the well-known Westinghouse "mill-type" motors being used and current furnished at 250 volts by two 750-kw rotary converters.

Shears, conveyors, and such other machinery as is in continuous operation will be driven by alternating-current, 220-volt induction motors.

The electrical installation is in charge of Mr. W. J. Beck. It is hoped to have the new plant running in less than a year, or about February, 1911.

New Laboratory.—The care and rigid inspection necessary in the manufacture of "American ingot iron" has resulted in the erection, now under way, of a new laboratory of research engineering.

This building is 40 x 60 ft., and will be provided with the most modern equipment on the market for conducting electrical and physical tests, as well as complete apparatus for the chemical and microscopical examination of irons and steels.

One section of the basement will be used for making accelerated corrosion tests, in which samples of iron will alternately be subjected to salt water and heated air. The automatic device for accomplishing this, which has been designed by Mr. J. A. Aupperle, chief engineer, consists essentially of a slowly revolving Ferris wheel about seven feet in diameter. A companion wheel will dip into fresh water.

Another feature of the corrosion investigations will be the carbonic-acid moisture tests in which a measured volume of illuminating gas is burned to produce moisture and CO_2 as suggested by Professor Charles F. Burgess, of the University of Wisconsin.

We hope to be able to give a more detailed description of the laboratory later. With its equipment it will cost $40,000, and is to be ready for service about August 1, 1910.

A New By-Product Coke Oven Plant.

The Bethlehem Steel Company has recently closed a contract through Messrs. Frederick J. Mayer and David B. Carse, of New York, with the Didier-March Company, a concern whose stock is largely held in Germany for the construction of a by-product coke oven plant which will be capable of coking about 4300 tons of coal per day, and an ultimate capacity of about twice this amount.

It is understood that the ovens used will be of the double underflue type, so arranged that there will be no reversing of the direction of the gases or the products of combustion. The ovens will have a capacity of about 10 tons each, there being in the first installation four batteries of 75 ovens each, or a total of 300 ovens.

This contract was made in the interest of the Berlin Anhaltische Maschinenbau Aktien Gesellschaft of Berlin, Germany, and the Stettiner Chamotte Fabrik Aktien Gesellschaft of Stettin, Germany. These concerns are the largest manufacturers in Europe of gas works, transmission machinery, by-product apparatus, and refractory materials. The Bethlehem plant will, therefore, be of the most modern type, with the latest machinery for the handling of all the materials.

It is understood that there will be installed a new process for the direct recovery of ammonia, a large briquetting plant, and apparatus for the distillation of tar. The coal storage will take care of 30 days' consumption at the rate of 8600 gross tons of coal per day, or sufficient for the doubling of the plant, which will soon be built.

It is reported that the interests building this plant are now active competitors for by-product plants in this country.

The United States vs. Anaconda Copper Mining Co.

Apropos the smelter fume problem which has occupied the attention of smelters and farmers for several years, it is interesting to note that the Federal Government has taken a hand for the purpose of protecting national forest reserves from alleged damage, and has sued the Anaconda Copper Mining Company, praying for an injunction to close the Washoe smelter in Montana. The Government's intention is to force the company to make such disposition of sulphur and arsenic fumes as shall render them innocuous. Experts for the Government claim that the outcome of other suits in California and Georgia has been an improvement in smelting methods, and will endeavor to force similar improvements in Montana. The Department of Justice has announced that the Montana suit will be pressed for a decree, unless Government experts con cooperate with the Anaconda company in terminating present conditions.

Institute of Metals.

The Council of the (British) Institute of Metals have decided to initiate what is hoped will be an annual series of May lectures.

The first of these will take place in London on Tuesday, May 24, when Professor Gowland, F.R.S., vice-president of the Institute, will deliver a lecture on "The Art of Working Metals in Japan," which will be illustrated by diagrams and lantern slides.

Chemists' Building in New York.

The Chemists' Building is progressing rapidly. The excavation of the site at 50-54 East Forty-first Street is nearly completed, and the bids of W. L. Crowe Company for the general construction, and of Chas. L. Eidlitz & Company for the electrical work have been accepted. A pamphlet will soon be ready for distribution among the membership of the Chemists' Club and other chemists, which will contain floor plans and other exact information. Barring unforeseen hindrances, the building should be ready for occupancy in January or February, 1911.

The chief features of the club's quarters have been previously detailed (see, especially, page 4 of our January issue); perhaps, however, some agreeable surprises will await the visitor. It has been found possible to carry out the architects' original plans in all essentials, and the building promises to be both useful and attractive.

Chemists should consider carefully the advantage of renting laboratories in the Club Building. So far, every profession has profited by concentration in a definite locality. The new Chemists' Building may seem to some rather distant from their old-time haunts; but within a year, their clients will be moving into its vicinity. The new Chelsea docks, as well as the Penn-

sylvania Station are causing merchants to consider Thirty-fourth Street the probable wholesale center; manufacturers are moving to Long Island and New Jersey; even the courts must inevitably find an up-town site.

The rentals will be moderate, and the arrangement of the flues, supply mains and chemical waste lines makes it possible to equip the laboratory according to one's fancy or needs, with the least expenditure of time and money. Then there is the proximity of a large consulting library. The possibilities of social and intellectual intercourse with men in the same line of work are multiplied to such an extent that the commercial chemist would find himself in a truly academic atmosphere.

A project will be submitted to the New York Section of the American Chemical Society at its next meeting, which, if adopted, will greatly enlarge the usefulness of the Chemical Museum for research, and here, again, proximity to a scientific center will prove advantageous to every tenant.

The Subscription Committee is not yet able to report the sale of all the stock, as $25,850 are still to be disposed of, and it is the duty of all those who desire to see the new building a success to relieve the burden of its managers as far as possible, and to do their best to interest friends in the enterprise, if they feel themselves unable to take a considerable number of shares.

The directors of the building company are Dr. Morris Loeb, Dr. C. F. Chandler, Mr. Albert Plaut, Mr. W. H. Nichols, Jr., and Dr. Leo H. Baekeland.

New York Section of the Society of Chemical Industry

At the meeting of March 25 of the New York Section of the Society of Chemical Industry (Mr. Maximilian Toch, chairman) an interesting lecture on color photography was delivered by Frederic E. Ives.

Messrs. L. H. Baekeland, Charles Baskerville, David Wesson, C. A. Doremus and Gustave W. Thompson were elected by ballot to serve on the executive committee for the ensuing year.

News from Niagara Falls

While the old established electric furnace industries of Niagara are in flourishing condition, interesting progress is also reported from the youngest of the large electrochemical works, the Hooker Electrochemical Company, which operates the Townsend process for the production of caustic soda and chlorine by electrolysis of brine. The chlorine is used in various ways, the chief product being bleaching powder; but electrolytic chlorine is now also attracting attention for metallurgical purposes.

Of special interest is the successful use in continuous commercial operation for several years of cell units with 2500 amp capacity and of very compact construction, and a recent large addition of units of 5000 amp capacity, illustrating the practical applicability of the principles of the Townsend cell. It may be mentioned that very favorable comment has been made on the cell by technical experts from Europe, who have visited the plant of the Hooker Electrochemical Company.

From the Canadian side it is reported that the works of the American Cyanamid Company in Niagara Falls, Canada, are in satisfactory commercial operation. The manufacture of commercial fertilizers from calcium cyanamide is stated to differ in various respects from European practice. The process of the American Cyanamid Company has been worked out to suit exactly the conditions of this country, especially the demand for a so-called complete fertilizer.

From Welland, Welland County, Ontario, it is reported that at the works of Electro Metals, Ltd., where ferrosilicon is principally made, extended experiments have recently been made on the baking of very large amorphous carbon electrodes. As is well known, this is a problem the solution of which increases in importance and difficulty with the increase of size of electric steel furnaces now being erected in various parts of the country.

The Iron and Steel Market.

April has brought fresh disappointment to the iron and steel trade, not because it did not bring an improvement in the market, but because it did not bring as great an improvement as was expected. While in the preceding months of the year actual engagements fell short of production, it is probable that on the whole fully as large a tonnage of finished steel was sold in April as was produced. In a sense the industry was "breaking even," but the spring is naturally the time for heavy buying, and unless general business conditions improve, buying is likely to be lighter in June, July, and August.

Upon the markets for wire and pipe there rested a heavy burden upon the opening of spring. In the closing months of last year buying in these lines, particularly by jobbers, was very heavy, and very large stocks were accumulated by reason of the general promise of the steel industry of higher prices this year. Through the winter the mills continued at full pace, and accumulated stocks of their own, so that the spring trade had two sets of stocks to liquidate. The movement into actual consumption was probably fully up to normal, taking care of the jobbers' stocks, but as there has been no particular prospects of price advances the jobbers have not bought heavily, and the mills are left with stocks. In no other branch of the finished steel trade has there been any curtailment of production, so far as can be ascertained, but in pipe and wire there has been curtailment, the Lorain pipe plant being closed during the early part of April and running at reduced output the remainder of the month, while the largest independent wire plant in the Pittsburg district closed April 9 for a short period to reduce stocks.

Other branches of the finished steel market have had sufficient vitality to maintain full production and the present outlook is for a continuance of full output for several months. At the same time the market entirely lacks the snap which has characterized the recent bursts of activity. In the three years of continued high pressure, from late in 1904 to late in 1907, mills were steadily falling behind in deliveries for more than two years, and prices were advancing, although not rapidly. Although business suddenly collapsed at the end of October, 1907, there was an advance in wire products on September 3 preceding, and a few months prior to that, on May 14, there was a large advance in pipe. At present the market shows none of that advancing tendency, although demand and production are 25 per cent. greater than in that period. The difference is made by capacity having increased just a trifle more than demand.

So far at least there is no evidence that the market is suffering from the fact that all efforts at artificial control were abandoned over a year ago. It is quite likely that if there had been artificial control during the second half of last year prices could not have been advanced as rapidly as they were by the eagerness of buyers to take what they considered bargains. They would probably have doubted the permanence of the advances, and this year, with demand less than was expected, they would probably have felt that prices were being artificially maintained, and would have bought less freely than they have in the actual circumstances, when it is known that each producing interest is working by itself.

Finished steel prices are substantially the same as at the opening of the year. From time to time there has been shading in some products, notably sheets and wire products, but the market has not become quotably lower. In structural shapes there has been a gradual weakening, by $1 a ton, and this concession, made early in the year only by Eastern mills, has in the past month become quite general.

Pig Iron.

From November 1 to April 1 pig iron production has averaged

each month at a greater rate than 31,000,000 tons a year, while October fell only a trifle below that rate. February showed the highest rate, 31,600,000 tons; March showing a drop of 400,000 tons to 31,200,000 tons. In no calendar year has as much as 26,000,000 tons been made, so that the industry has been running at a stupendous pace. The decrease in production in March was wholly by steel works, the merchant furnaces increasing their output. This was unnatural, for the merchant furnaces have been accumulating stocks, and should have reduced production. They have been doing so of late, several stacks having gone out in April, while more are certain to go out in the next two months. Prices have continued to weaken, although very slightly. Prices at valley furnaces (90 cents higher, delivered Pittsburg) stand quotable at $16 for basic, $17.50 for Bessemer, $15.75 for No. 2 foundry, $16 for malleable and $15.25 for forge. The Southern market has dropped 50 cents since last report, being quotable at a minimum of $12. At this figure there is the first definite resistance to decline. The Southern furnaces, however, have a larger margin than have the Northern furnaces, which must buy ore and coke. Some Central Western furnaces have not bought ore for the season, and perhaps will not unless conditions improve, preferring to go out of blast. For the first time the competition of furnaces owned or controlled by ore interests promises serious results to the purchasing class, for there is now a large production by them, and more are being built by ore interests, for no less than eight merchant furnaces at Chicago, Detroit, Cleveland, Josephine and Buffalo, are being built by Lake Superior ore interests, two of these, at Detroit and Cleveland, being practically completed.

Steel.

Bessemer steel has weakened, while open-hearth steel is, if anything, stronger than it was a month or two months ago. The weakness in Bessemer steel is directly attributable to the light demand for rails. A Bessemer steel interest just east of Pittsburg has lately become a producer of sheet bars and entered the Pittsburg market early in April with cut prices on both billets and sheet bars. Prices are roundly quotable as follows: Bessemer billets, $27 to $27.50; sheet bars, $27.50 to $28; open-hearth billets, $28.50 to $29; sheet bars, $29 to $29.50; all f.o.b. maker's mills, Pittsburg or Youngstown districts. Rods are nominally $33, Pittsburg.

Wages.

Early in April the Pennsylvania Steel Company, for its own operations at Steelton and the Sparrows' Point operations of its subsidiary, the Maryland Steel Company, announced a wage advance of about 6 per cent. Shortly afterwards the United States Steel Corporation announced an advance, for May 1, averaging about 6 per cent. for its blast furnace and steel works employees in the North. There had been an advance in Connellsville coke wages January 16 and an advance in the Lake Superior ore region at the beginning of mining. The question of advancing wages in the South, and of advancing wages upon its railroads, was left undecided. Other iron and steel interests in the Central West will presumably be moved by the incident to make corresponding advances. Many of the railroads have made wage advances averaging about 6 per cent.

These wage advances are based upon the unrest of labor and the "increased cost of living." As shown by the Index numbers of commodity prices, there has been a decided increase in the cost of living since 1907. The steel industry, however, is obtaining from $3 to $5 a ton less for its products than in 1907, and while prices were slightly higher, on an average, than in 1906, there was a general wage advance at the beginning of 1907. There has been no wage reduction since 1907, except that in the spring of 1909 there was an abortive movement to reduce wages, but former wage scales were soon restored.

Thus the steel industry is paying higher wages and getting less for its product. The trend is a very unfortunate one. The cost of steel production is altogether too high for the circumstances in which the industry finds itself.

Finished Products.

Regular prices, f.o.b. Pittsburg, are as follows:

Standard steel rails, $28 for Bessemer, $30, for open hearth; f.o.b. mill, except Colorado.

Plates, $1.55 for tank quality, ¼ in. and heavier.

Shapes, $1.50 to $1.55 for I-beams and channels, 15 in. and under, zees and angles, 2 x 3 and larger.

Steel bars, $1.45 to $1.50, base.

Iron bars, $1.60, Pittsburg; $1.50 to $1.60, Philadelphia; $1.50, Chicago; $1.40 to $1.45, St. Louis.

Wire nails, $1.85, base; plain wire, $1.65, base; galvanized barb wire, $2.15.

Black sheets, 28 gage, $2.40; galvanized, $3.50; blue annealed, 10 gage, $1.75 to $1.90; plainted corrugated roofing, $1.70 per square; galvanized, $3.

Tin plates, $3.60 to $3.75 for 100-lb. cokes.

The Non-Ferrous Metal Market.

Practically no interesting features have characterized the base metal market for the past month, and no transactions worthy of note have been reported. Temporary improvement has been noted on one or two occasions, but there has been a general evidence of weakness. The feeling prevails that the delay in the anticipated spring buying has contributed to the lack of firmness in the market.

Copper.—The only feature in the copper market in the last few weeks was the sharp decline in lake on April 11. This followed a period of dullness, and was due to the decision of the Calumet and Hecla to offer copper at 13c. instead of 13.75c. The effect was to stimulate sales, both foreign and domestic, and some good orders were booked. The action of the Calumet and Hecla may have been influenced by the American statistics for March, which were regarded as unfavorable on account of the increase in the world's visible supply. Electrolytic has shown the same features as lake.

Tin.—The market for tin has been unsteady and unsatisfactory, with practically no demand. Domestic sellers recently offered the metal below the import basis, but buyers did not take much for future delivery. Prices have varied a little during the month, but at the close of the market on April 13 tin could be bought at 32.40c.

Lead.—This metal has shown a steady decline for several weeks. The reluctance of the consumers to buy at the prices offered has resulted in a dull market. The reductions made by the American Smelting and Refining Company have been met promptly by other sellers, but no large sales have been made. At the close of the market April 13 lead was easy at 4.35 to 4.40c. New York, and 4.20 to 4.22½c. St. Louis.

Zinc.—Nominal prices have been the rule for some weeks, and liberal offers failed to find ready buyers. Prices have dropped steadily until the close of business April 13 showed spelter offered at 5.50c. in New York and 5.35c. in St. Louis. Other metals except aluminium have shown little or no feature. Business has been active in all branches of the aluminium trade and the production is being bought up steadily.

CORRESPONDENCE

Electric Steel Refining.

To the Editor of Metallurgical and Chemical Engineering:

Sir:—The article in your April issue on the South Chicago Electric Furnace Plant of the U. S. Steel Corporation is of considerable interest. After we have heard so much as to what could or might be done with the electric furnace in the electrometallurgy of iron and steel, it is refreshing to read a simple statement of what is being done in South Chicago with the 15-ton Héroult steel-refining furnace on a thoroughly commercial scale in every-day work.

While the object of your article was evidently to state

simply facts, without any theoretical discussion, some interesting deductions can be drawn directly from the facts given in your article. The question has often been asked what is the rationale of the success of refining steel in the electric furnace and the answer has usually been that two causes are contributory to success—the possibility of producing a very high temperature and the neutral or reducing atmosphere of the electric furnace.

Now, the figures of temperature given in your article show conclusively that the possibility of producing a very high temperature in the electric furnace is not utilized for steel refining, at least not in the practice of the Illinois Steel Company at South Chicago. The steel in the electric furnace is not much hotter than when it comes from the Bessemer converter. Hence the success of refining steel in the electric furnace should be attributed essentially and primarily to the neutral atmosphere alone, which permits reactions (deoxidation and the specific reactions in the Héroult furnace by which sulphur and phosphorus are removed) which are impossible in oxidizing furnaces.

Chicago, Ill. M. N.

* * *

Rapid Electro-Analysis with Stationary Electrodes.

To the Editor of Metallurgical and Chemical Engineering:

SIR:—I notice in your April issue an abstract of an article by Perkin and Hughes in which they describe some new forms and details of rotating electrodes for the quantitative determination of metals by electrodeposition. A number of articles have appeared lately dealing with this subject, interest being aroused to a great extent no doubt by the advantage, and in many cases by the necessity, for more rapidity.

This being the case it seems strange that an article by Dr. John T. Stoddard, which appeared in the *Journal* of the American Chemical Society for March, 1909, in which he brings out the merits of the stationary wire gauze cathode, should have received apparently so little attention. This article has been abstracted and, I believe, reprinted in full in the *Chemical News*. Also, other experimenters, for instance L. S. and R. C. Palmer, in a paper read in May, 1909, before the American Electrochemical Society, have confirmed to a large extent the results obtained by Dr. Stoddard, but in spite of this publicity many investigators, notably Perkins and Hughes, do not appear to be aware of the method as suggested in that article, or, if they are, do not consider it of importance.

In the opinion of the writer it is worth very serious consideration, especially as Dr. Stoddard has worked out the details as they occur in actual laboratory work quite thoroughly, and in adapting it to the work in this laboratory few changes were made, and these only in some comparatively unimportant details.

Some time previous to the appearance of this paper the increase of work in this laboratory necessitated some more rapid method for the determination of copper, and the rotating anode was tried with both a platinum dish and a mercury cup for the cathode. In spite of the time saved by the rapid precipitation it was soon recognized that in a laboratory connected with a manufacturing plant where "results" are wanted with as much rapidity as is consistent with accuracy, rather than "material" for papers, the apparatus necessary to the rotating method was not, to say the least, desirable.

Dr. Stoddard's article appeared about this time and was recognized as a step forward, provided it proved practical and accurate, which it has.

In this laboratory the gauze cathode is the same as described by him, and is a cylinder 1¼ in. in diameter by 1¼ in. in length, made of 52 mesh platinum wire gauze. At each end of the cylinder the gauze is folded over a platinum wire 0.02 in. or 0.03 in. in diameter, and the whole soldered to a platinum wire stem about 0.05 in. in diameter and about 6 in. long, the cylinder complete weighing about 10 grams.

The anode is a platinum wire (0.05 in. in diameter) spiral with seven or eight turns in a length of ¾ in., with enough extra wire to make a straight stem 2 in. or 3 in. long. The outside diameter of the spiral is 7/16 in.

This anode is different from that described by Dr. Stoddard. It was intended to follow his description and use a platinum foil cylinder for the anode, but through some oversight none was on hand when everything else was ready for a start, so in order to get quick action a platinum wire was coiled up in a spiral form and pressed into service. It was so successful, appearing to possess the slight advantage of allowing better circulation of the electrolyte, that it has been retained.

At first, naturally, strong currents and rapid deposition were in order. With a current of 8 amp (furnished by a storage battery), or even more sometimes, the copper in a 1 gram sample of brass containing 85 per cent copper was precipitated in 12 or 15 minutes. It was found after a time, however, that this speed carried disadvantages—disadvantages, by the way, which are not necessarily overcome by the rotating electrode. The last traces of copper were apt to be left in the solution, and it required close attention, on the other hand, to see that the strong current did not decompose all the acid, indicated by a tendency to foam, and in this way spoil the work.

The current was dropped to 6 amp and the time at this rate was about 20 minutes, with better results. Gradual changes were made, based on more experience, until now the start is made with 4 amp (increased to five or six for the last few minutes), and the time allowed is 30 minutes.

At this rate, working on a 1 gram sample, it is very rare indeed that the last traces of copper are not removed, whether it is a yellow brass containing 60 per cent of copper, or a sample of ingot copper containing practically 100 per cent, and on the other hand, there is no danger of the acid being all decomposed. It is just as simple as, and requires no more attention than, the old over-night method, and yet is comparatively rapid.

The deposition of the copper is made in a volume of 60 c.c. to 70 c.c. and at a temperature nearly or quite boiling. In the regular course of a brass analysis the electrolyte would contain 5 c.c. of concentrated sulphuric acid minus what would be lost in evaporating for the lead determination, and to this is added ½ c.c. strong nitric acid. Under these conditions the precipitation is very simple and satisfactory.

The method is equally advantageous in the determination of nickel which is deposited under practically the same conditions as copper, with the exception that the current is usually on a few minutes longer. There has been little occasion or opportunity to experiment with metals other than the above, but Dr. Stoddard's work would indicate that it can be employed to advantage on other metals.

ALLEN P. FORD.

Laboratory, Crane Valve Company, Bridgeport, Conn.

* * *

Efficiency of Dryers.

To the Editor of Metallurgical and Chemical Engineering:

SIR:—Mr. Ruggles' reply to my criticism—not of the dryer test,—but of a misuse of the word "efficiency" in describing the performance of the machine hardly seems sufficiently to justify the new and unprecedented meaning with which this term has been invested by him.

I believe it will hardly be questioned that the definition I have given of "efficiency," as applied to the performance of any machine, conveys its meaning as universally understood by engineers and scientists, and any technical man on hearing that the efficiency of a machine was 85% would instinctively understand this as being meant in the ordinary and accepted sense.

Mr. Ruggles is perfectly correct in saying that he had fully stated his position as regards "loss of heat in dried material,"

in a preliminary paragraph, but while as he says, "there could be no possible deception," there is, in this misuse of words, abundant opportunity for grave misconception as to the performance of the machine,—the more so as the article was introduced by a comment on the remarkable efficiency attained.

True, the discussion is one of terms. What other form could such discussion assume? It may be open to the stigmatization of being "academic," but not necessarily therefore unprofitable, for, if it be legitimate to use one word in a novel and entirely arbitrary sense, widely differing from its accepted technical usage, where shall the line be drawn? Why may not the next account of a dryer test use B. T. U. with a new and special value to suit the exigencies of the case?

While the discussion may be academic, the correct understanding of the performance of a machine is intensely practical. With some uncertainty as to whether "academic" or practical, I would point out that Mr. Ruggles' defence of his method of computing "efficiency" (in his second paragraph) is not valid, nor is the distinction drawn between "necessary" and "un-necessary" losses a correct one.

The losses (departures from theoretical perfection) in any well designed machine are all necessary. Good design reduces losses to a minimum. Unnecessary losses are, de facto, the marks of poor design.

Loss by radiation in any heat-using machine is, practically speaking, a "necessary" loss. It can, in no practical way, be avoided, but, by good design, may be reduced. Similarly in any fuel-burning machine loss by unconsumed fuel is unavoidable and, therefore, necessary, but, by good design of furnace, it may be reduced to a minimum.

In a dynamo, loss by heating of the armature is "necessary," and so on indefinitely. With precise similarity, loss of heat in dried material is inseparable from the operation of any practical dryer, but may be minimized by modified design or mode of operation.

In every case cited, in speaking of the efficiency of the machine we mean its utilization of energy *in useful work after deducting all losses* and not after crediting the machine with one of the major losses on the ground that it is necessary.

Nor is Mr. Ruggles correct from a purely practical standpoint in assuming that "it is necessary to heat such material (sand) to 212°." Nor again, that "to attempt to dry sand, etc. * * * at a low temperature by absorption would be absurd on account of the small capacity such a process would give." If I correctly understand the last quoted sentence, "drying at a low temperature by absorption" means drying under such conditions that all the moisture is carried off as vapor by the air (or gases) passing through the dryer, such gases being discharged partly or completely saturated at a temperature below 212°. If this understanding be correct, such a process would by no means be absurd; nor, to attain a capacity equal to that described in the test under discussion, would it involve any extraordinary conditions—either as to size of apparatus, initial temperature, volume of air, or in any other way. Furthermore, it is entirely practicable to discharge the dried material at a temperature far below 212° and hence greatly to diminish the "loss of heat in dried material."

This loss, which in Mr. Ruggles' case far exceeds any other, is, as I have already pointed out, one of which the magnitude is largely dependent upon the design of machine—one which can be materially reduced and which differs in no essential from any other source of loss. There is absolutely no legitimate reason for according to it a special treatment.

Mr. Ruggles' position would be correct only if the dryer be considered as a machine for *heating* sand. Such is not its true function, which is purely evaporation of water, and any heat diverted from the true function of the machine is wasted as regards the specific end to be attained and, therefore, detracts from "efficiency."

The 85% efficiency claimed represents no real thing. It stands for no actual tangible accomplishment of the dryer and conveys no correct concept of the merit or demerit of its performance. The 85% efficiency is a fanciful and ideal figure, compounded of the actual useful performance in drying, and the useless waste of heat in dried material. If it means anything at all, it must be regarded as expressing the compound efficiency of the machine as a dryer and a sand heater.

"Efficiency" has hitherto been a useful and respectable member of the community of words, but we may well shudder for its future reputation, if such hybrid and illegitimate concepts are to be fathered upon it.

To sum up:—My letter in your April issue was a protest against using "efficiency" in a sense differing radically from its accepted technical meaning,—a transgression that is hardly palliated by a statement of position as regards a certain loss in another part of the article.

I contend that any one reading the article in question, with its deduction of 85% efficiency, would primarily understand that the dryer had, in the test described, utilized in useful work 85% of the heat supplied to it, instead of only 54.5% as was actually the case.

Only after a somewhat careful study of the figures does the fallacy become apparent, and then only to those having some familiarity with the science of drying.

Whatever the 85% represents, if indeed it represents anything, it certainly does not express the efficiency of the machine as a dryer.

Therefore, without implying any intent of deception, the erroneous use of the word "efficiency" certainly does convey, in the article discussed, a quite erroneous idea of the actual performance of the machine under test.

Bayonne, N. J. W. E. Wadman.

* * *

To the Editor of Metallurgical and Chemical Engineering

Sir:—From Mr. Wadman's point of view, taking one particular kind of material, his position may be correct, but in drying over 40 different kinds of material under the greatest variations of moisture and temperature, there can be but one way of figuring the efficiency of dryers so as to bring them all under a uniform rating, and this is the system which I have adopted and which I maintain is perfectly fair as long as the purchaser and user understands the basis of comparison.

A great many dryers are sold for drying and heating sand in asphalt work where it is necessary to raise the temperature of the sand to 400° to mix with the melted asphalt without chilling it. In this case Mr. Wadman would credit the heat carried out with the sand and make the efficiency of the dryer 88 per cent, while the same dryer drying the same sand for a plaster mill would only have an efficiency of 54 per cent.

In many other cases the material after drying has to be heated either to calcine it, to burn out organic matter, or for some other special reason. In drying granulated blast-furnace slag, the water is imprisoned in cells so that a temperature of at least 250° has to be given to the material in order to burst the cells and release the water.

In some cases, as with cement rock, the moisture to be evaporated is not over 1 per cent, in which case Mr. Wadman would only credit the dryer with 22 per cent efficiency, while the same dryer drying a precipitate carrying 60 per cent of water he would give an efficiency of 83 per cent. This is rather an absurdity when the dryer in one case is as efficient as in the other. With my method of calculation any one type of dryer will give practically the same efficiency under any or all conditions and different types may be compared even under totally different conditions. By charging the dryer with only unnecessary losses, such as imperfect combustion, heat lost in exhaust, in radiation and in dried material above 212°, and by crediting it with the necessary heat of material up to 212°, no injustice is done and the question is much simplified.

New York City. W. B. Ruggles.

The New Blast Furnace of the Bethlehem Steel Company—1.

BY W. S. LANDIS, M.S.

On Thursday, April 7, Furnace "D" of the Bethlehem Steel Company was lighted by the veteran ironmaster, Mr. John Fritz. The company had invited several hundred representative citizens of the Bethlehems and adjacent towns, as well as students of the Lehigh University, to the interesting occasion, they meeting at the offices of the company and being led by President Schwab to the new furnace, heartily cheered "Uncle John" and President Schwab as the torch was applied. After the lighting they again returned to the offices, where a reception was held, at which speeches were made by Mr. Fritz and the officials of the company. With all his long and active career in the iron industry Mr. Fritz acknowledged this as the first time he had ever set a furnace in operation himself.

Some 50 years ago this summer the first blast furnace of the old Bethlehem Iron Company was built. Four others followed it at various intervals, the four still being in active operation though the original one has long since been demolished. These four furnaces are 18 ft. x 70 ft. and have capacities of 200 tons of basic iron per day. In April, 1906, work was commenced on a 22 ft. x 90 ft. stack in anticipation of the demands of the new rail and structural mills begun in the fall of this same year. This furnace, designed by the Bethlehem Steel Company and built by the Riter-Conley Company, was the

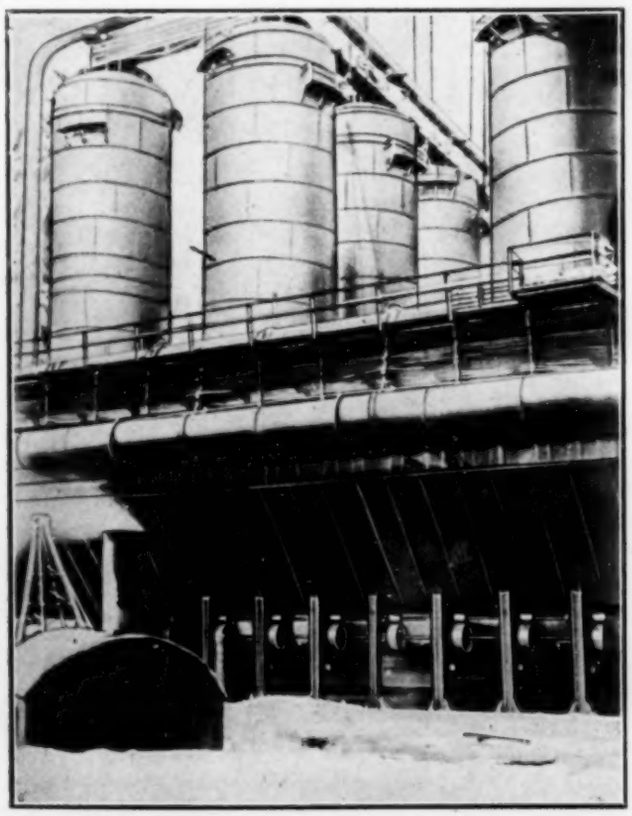


FIG. 1.—ORE BINS.

prototype of the furnace just lighted, though in lines and general arrangement only.

In 1908 the steel company determined to install an addition to their steel mills, the present 35,000 tons capacity per month not nearly sufficing to keep up with their orders. This addition is to take the form of a duplex plant, similar to the one at Ensley, Ala.

To meet the demands of this new plant for pig iron another furnace was determined upon.

Work being somewhat slack in the construction departments of the works it was determined to undertake the construction of this new furnace at home in order to keep up the personnel of the various departments during dull times. Every drawing, and every part of the furnace with the exception of a traveling crane and two motors entering into the whole construction, was built by the Bethlehem Steel Company themselves in their own shops, the construction being almost entirely in the hands of Mr. W. F. Roberts, assistant general superintendent. The entire

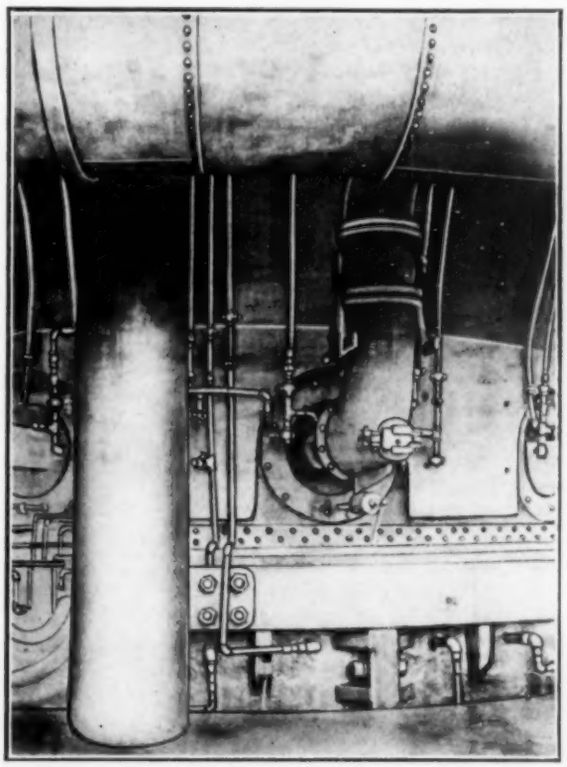


FIG. 2.—PORTION OF BOSH.

work was completed in an actual working time of eight months, and at considerable saving over contract work, both in time and money.

Although it is intended to give a complete description of the many novel features of the furnace in detail in Part II of this paper (to be published in the next issue), it might not be out of place here to call attention to the general equipment of Furnace "D." The ores used come from the Santiago district, Cuba, and are rather refractory, necessitating high temperature of blast for successful treatment. For this reason ample stove capacity in the shape of five 22-ft. x 100-ft. McClure-type stoves has been provided. To ensure these stoves working at their maximum efficiency it was necessary to provide at the same time a most elaborate system of gas-cleaning apparatus, the gases passing through a conical dust-catcher, a Mullen washer and three 12-ft. x 75-ft. Steinbart towers with interior rain-makers, before going to the stoves. Attention will again be called to this feature of the furnace.

Fig. 1 shows the ore bins with elevated railway for carrying stock from the yard to the bins. This railway is over half a mile long and extends the full length of the present furnace equipment, embracing five furnaces. Just above may be seen the stoves and to the extreme left the stack. The steam shovel in the foreground is excavating for the foundations of the new blowing house, gas engines of the company's own manufacture to be installed as rapidly as they can be built. At present the surplus power of the other furnaces is used to drive Furnace "D."

Fig. 2 shows a portion of the bosh, a tuyere connection and at

the lower left the emergency tap hole. The cooling system of the bosh is unique and will be referred to in detail later.

Fig. 3 is a general view of the interior of the cast house, the skimmer being at the extreme left. The ladle cars, carrying the metal to the mixer in a steel mill a mile away or to the casting machine, run in under the floor, the illustration showing the various runners and gates controlling the flow of metal.

The slag cars come in on a track laid in the pit between the

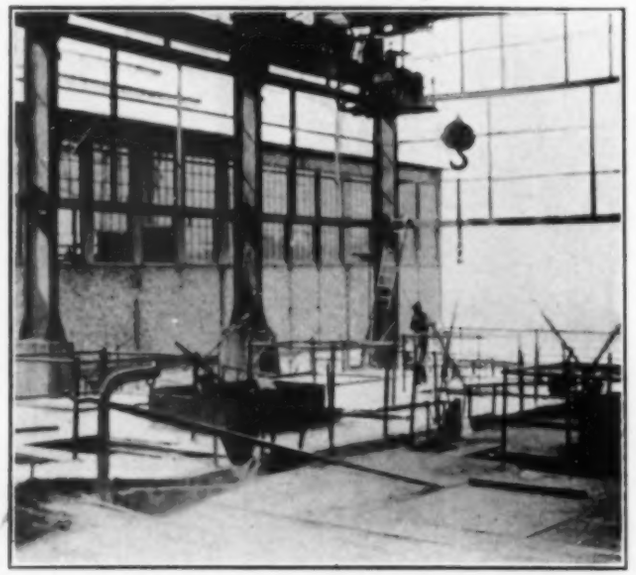


FIG. 3.—CAST HOUSE.

cast house and the boiler house on the left. A 25-ton crane has proven itself a most useful adjunct to this portion of the furnace.

One cannot help but marvel at the cleanliness of the cast house, the visit of the writer having been unannounced and no special dressing up having been done. The same cleanliness is

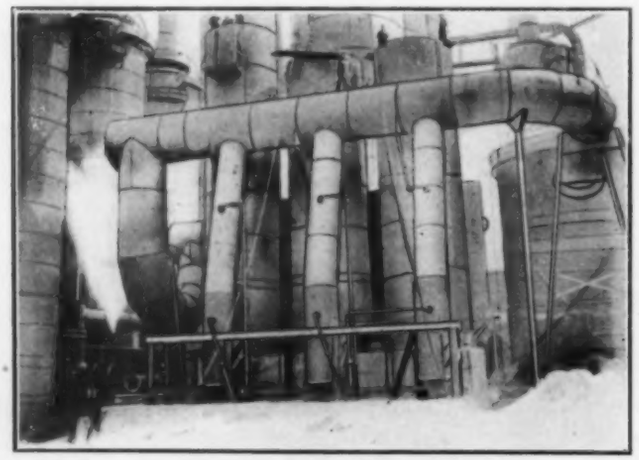


FIG. 4.—STEINBART TOWERS.

everywhere evident around the furnace, concrete floors with convenient sewer outlets greatly assisting in its maintenance.

Fig. 4 shows the Steinbart towers during erection. The furnace was in operation at the time this photograph was taken, the gas from the Mullen washer on the right being shunted around the towers through the large inverted siphon at the left. Similar siphons connect the washers with the gas mains, no valves being used other than water admitted or run out of these siphons.

The rated capacity of the furnace smelting hard ores is 450 tons per day, using 41,000 cu. ft. of blast per minute. The total capacity of the whole blast furnace equipment at present completed is 1500 tons a day. With the completion of the duplex steel plant it is estimated that at least 2500 tons of pig per day will be required.

The company has, therefore, let contracts for two similar furnaces to "D" to the Pennsylvania Engineering Company, of New Castle, Pa., work on which has just been started. An interesting feature of this new work is the large traveler used for handling the material entering into the construction of the 10 stoves and two stacks.

Fig. 5 shows it in operation setting plates on one of the stoves of furnace "F." It is 125 ft. high, weighs 140 tons and cost alone $10,000. The boom is 90 ft. long, sufficient to reach to the furthest stove on the left. The extremely heavy bracing in the lowest story is necessitated by the fact that the traveler spans the track leading to the slag tap of furnace "E."

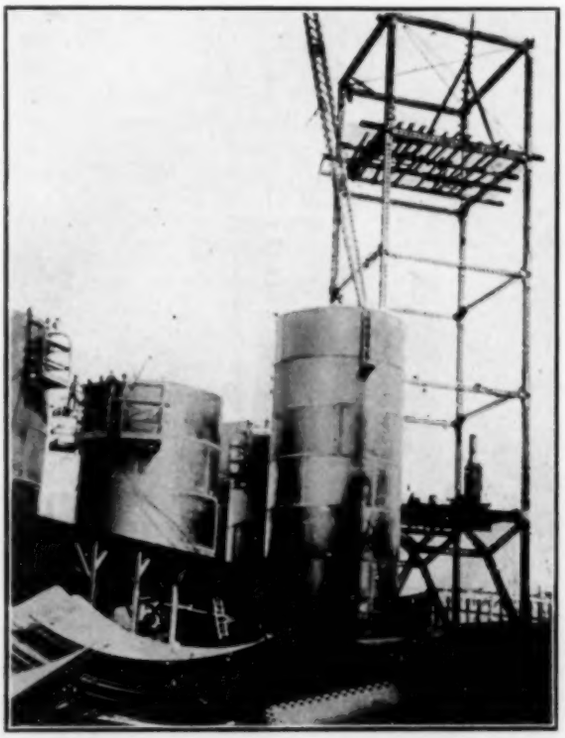


FIG. 5.—TRAVELER.

In concluding this portion of the description the charge sheet of the furnace for its first filling will be given. The furnace was scaffolded as usual, 16 ft. of cord wood being used. Next 21 rounds of coke (10,000 lb.), 21 rounds of blast-furnace slag (2000 lb.), and 21 rounds of stone, half dolomite and half calcite (1600—2100 lb.). Then 7800 burden was added per round of coke, this being increased by 400 lb. each fifth round until the full charge in the furnace, limestone increasing correspondingly 100 lb. every tenth round. At 3:30 p. m. the torch was applied. At 4 p. m. the blowing engines were started at 9000 cu. ft. of air per minute. Slag was tapped 17 hours after lighting and iron 24 hours.

Columbia Night at the New York Chemists' Club.—The smoker held at the Club House on March 26 was the second in the series of college evenings which are being given by the Club. This time it was Columbia night and a representative delegation from the faculty was present, including Dr. Chandler, Dr. Bogert, Dr. Metzger, Prof. Gies, Prof. Sherman, Prof. Coblentz and Prof. Woodhull. Prof. Morgan and Prof. Tucker had sent papers.

Electric Furnaces in Non-Ferrous Metallurgy.

BY JOSEPH W. RICHARDS.

The electric furnace is monopolizing attention to such a great extent in the metallurgy of iron and steel that its use in the metallurgy of the other metals is being relatively neglected. The interests involved in the manufacture of iron and steel are so great that any suspicion that the electric furnace is able to bring about a revolution in the manufacture of pig iron, structural steel or fine steel, focuses the attention of metallurgists on these possibilities.

Signs are not lacking, however, to indicate that non-ferrous metallurgy may likewise be deeply concerned in the development of the electric furnace. The recent great advances in electric steel furnaces have given us furnaces of great capacity, which are equally suitable for use in non-ferrous metallurgy. The electric shaft furnace for pig iron manufacture is simply an improved electric shaft furnace suitable for any kind of shaft furnace work, and may quite possibly find as large application in non-ferrous metallurgy as in the manufacture of pig iron.

The furnace operations of non-ferrous metallurgy are very diverse; the principal ones are:

(1) The melting of metals for refining and casting.

(2) The melting together of metals to form alloys.

(3) The roastng of sulphide and arsenide ores.

(4) The concentrating smelting of raw or partly roasted ores to matte.

(5) The reducing smelting of raw or roasted ores to metal.

(6) The reducing smelting of raw or roasted ores to metal vapor which is to be condensed.

I. The non-ferrous metals are in general so valuable and so easily injured in quality by furnace gases that they are usually melted in pots, crucibles or muffles. The same is true of fine steel, up until recently melted only in crucibles. The great development of electric steel melting furnaces has a direct bearing on these non-ferrous operations. What can be cleaner and neater than, for instance, the melting of gold or silver in an induction electric furnace, using no fuel, producing no ashes, employing no agent which can contaminate the metal, carrying off no metallic vapor by the stream of hot furnace gases, and with the temperature controllable to a nicety by the revolving of a resistance-box handle? And what is true of gold and silver is true, in many cases, to a greater extent, of copper, zinc, nickel, aluminium, magnesium, platinum, etc. The advantages of the electric furnace melting of these non-ferrous metals are either unrecognized or are only beginning to be appreciated.

II. The non-ferrous industries manufacturing alloys will gain particularly by the use of electric melting furnaces. As is generally recognized, it is the atmosphere of the ordinary melting furnace which plays havoc with the quality and proportions of the alloy with which it comes in contact, while the hot gases carry off considerable quantities of metallic vapor. To obviate these losses and changes in the composition, careful melting is done in closed crucibles, with all their attendant disadvantages of high fuel consumption, cost of wear and tear, and small heats.

The electric furnace provides the means for producing at one heat a ton or even several tons of alloy, all uniform in composition, and without any necessary losses by oxidation or changes in composition. In other words, just as in the steel industry, it provides *crucible quality* metal in the large heats furnished by the hearth furnaces, and at almost the price of operation of the latter.

We confidently anticipate a great extension of the use of electric furnaces in the manufacture of such alloys as are usually made to best advantage in crucibles, such as brass, bronzes, German silver, coin silver, alloyed gold, and in general all the more difficultly fusible alloys which cannot be safely melted in the ordinary iron melting pot.

III. Turning now to the metallurgical treatment of non ferrous ores and intermediate products, we consider first the roasting operation, ordinarily undertaken to remove sulphur and arsenic. These depend primarily on oxidation by the air, at a carefully regulated temperature, which will not melt the sulphides or arsenides present. These operations ordinarily require little and sometimes no fuel, because the heat of oxidation of the ore itself furnishes considerable heat.

When the ore is thus self-roasting it is self-evident that no electrical assistance is necessary or required. Where supplementary heat is needed it may in all cases be furnished with advantage electrically if it can be furnished cheaply enough. If fuel is burned to supply the supplementary heat, the fuel itself and its products of combustion interfere with the roasting operation if they are mixed with the ore and burned by the same air which does the roasting; if the fuel is burned separately and its heat of combustion transmitted to the roasting material through the walls of a retort or muffle, then such heat is applied ineffectively. That is, with but poor heating efficiency.

In the case of using electrical energy for this supplementary heating, it has the advantag. of exerting no hindering action whatever upon the roasting operation, and it may be applied either by direct heating of the ore by its own resistance or by transmission from an electrically heated resistor through the walls of the retort.

In any case, the substitution will have advantages in the roasting operation, and will be advisable if the electrical energy can be obtained cheaply enough. That will be the principal question to be considered; where fuel is dear and power is cheap, the substitution may easily be of economic advantage, especially in attaining "dead" or complete roasting.

IV. The concentrating smelting of raw ore or partly roasted ore to sulphide matte is an operation carried on on an enormous scale in non-ferrous metallurgy. There is nothing analogous to it in the metallurgy of iron with which to compare it. The gangue of the ore and fluxes unite to form a fusible slag, as in the iron blast-furnace, but the metals remain combined with sulphur and concentrate as melted sulphides, instead of as melted metal.

In some cases the charge contains so much iron sulphide (pyrites) that the heat of its oxidation by the blast is sufficient to replace all other fuel, and we have an auto-smelting operation similar in thermal characteristics to the auto-roasting previously mentioned, and known usually as "pyritic smelting." Such an operation is highly desirable where possible, because it furnishes matte and slag, utilizing only the self-contained fuel of the ore: The heat of oxidation of part of its iron and sulphur. Electric heating has nothing to do with such an operation.

In the majority of cases, however, the raw ore or partially roasted ore cannot be "pyritically" smelted, and supplementary fuel is necessary. The products of combustion of this fuel, mixed with the charge, are not favorable to the concentrating operation, since they hinder its oxidation. If electrical heating is used in such a shaft furnace it will supply the deficit of heat needed without absorbing any of the oxygen of the blast.

Some of the electric shaft furnaces already operated would be fitted for these operations if provided with tuyeres above the electrodes in order to perform whatever oxidation of the sulphides of the charge was desired. The air supply thus furnished would have to be regulated closely to accomplish the amount of oxidation required and the production of the desired quality of matte, while the electric current would be regulated to provide the heat deficient for the smelting operation.

A furnace thus operating would probably run more smoothly than a furnace running "semi-pyritically," that is, with some fuel, because the amount of oxidation could be regulated exactly by the blast used and the heat supply by the electrical energy. It would be cheaper run electrically only where fuel was high in price and power cheap.

V. The reducing smelting of suitable raw ores or "dead

roasted" ores to metal is a different class of operation. One phase of it is distinctly analogous to the shaft furnace reduction of iron ores. The charges may be oxide of a metal, such as copper, nickel, lead, tin, antimony, even zinc together with the gangue of the ore, flux and a reducing agent.

As ordinarily operated, the charge is either heated by fuel mixed directly with the charge, as in shaft furnaces, or by fuel burned apart, as in reverberatories.

In reverberatories, enough fuel is mixed with the charge to reduce the metallic oxides, and the whole is heated by gases from a fireplace. The efficiency of such a scheme of heating is low; usually less than 25 per cent. of the heating power of the fuel burned on the grate is usefully applied to heating the charge, the rest being lost by radiation and conduction and sensible heat of the furnace gases, while the large volumes of gases superficially heating the charge usually carry off considerable metallic vapors into the chimney flues.

Electrical smelting of such a charge should be highly advantageous in respect to saving of metal, if the cost of the electrical energy compared to that of the relatively large amount of coal used made the change possible.

In shaft furnaces, fuel is mixed with the charge for the double function of chemical reduction and to furnish heat by its combustion at the tuyeres. The operation is a duplicate of iron blast furnace operation, except that in the case of somewhat volatile metals, like tin and lead, great losses may occur, while with zinc all of it would be driven out in the fume, and the shaft furnace is impossible.

For such shaft furnace reduction processes, the electric shaft furnace, as already built and operated, should prove itself very well suited. Its advantages are the absence of the large volume of products of combustion of fuel, and consequent great decrease in volatilization and fume loss; the absence of the relatively high temperature of combustion in the tuyere region, and the regulation of the maximum temperature in the furnace to simply that required for the running out of the products. These changes would increase greatly the regularity of running, and decrease to practically nothing the volatilization loss. Of course, sufficient carbon for reduction of the charge must be used, but none for fuel. The amount of electric power required would be small, even for large furnaces, since the heat requirements are not large.

Quantitative calculations can be made for any given locality, comparing the cost of electric smelting of any given ore to metal in the electric shaft furnace, with its reverberatory or blast furnace smelting. The writer is confident that there are localities where the conditions already exist which would make the electric shaft furnace smelting preferable to the older methods of non-ferrous metallurgy. The whole problem is very recent, and the questions involved have scarcely received any proper amount of intelligent consideration.

VI. Reduction to metallic vapors, with subsequent condensation thereof, is the problem *par excellence* of the zinc industry. It cannot be done in shaft furnaces, because the products of combustion of the fuel mixing with the metallic vapors prohibit their condensation. The only remedy is to enclose the ore mixture in retorts and supply the necessary heat from outside. This is highly inefficient of fuel, because the sides of the retorts are poor heat conductors, and the thermal efficiency of such furnaces is therefore very low.

Electrical heating offers great promise of revolutionizing such metallurgical operations. Electrical energy can be converted into heat *inside* the retorts, thus furnishing most economically the desired heat supply without having any but the usual gases in the retort. The problem is not a simple one. The iron and steel furnaces offer very little or no assistance in working out the problem, because no analogous problem arises in that industry. Many metallurgists are at present working on this problem, and at any time we may be able to chronicle the successful solution of the problem.

When the problem is finally solved electrically, it may result in the removal of our zinc works to cheap power supplies. Italy produces large quantities of zinc ore, for instance, but smelts practically none of it, because of lack of fuel; a successful electrical zinc furnace would enable Italy to utilize her "houille blanche," or "white coal," from the snow-capped Alps, and keep her zinc industry at home, where it should be.

We are, moreover, confident that a good working electrical zinc furnace is not far away, and when it arrives electrometallurgy will make one more change in the commercial map of the world.

All in all, may we not well say that electrometallurgical apparatus and processes are the most interesting, the most attractive, and potentially the most powerful of the chemical and metallurgical agents and reagents at our command?

Lehigh University.

Commercial Oxygen.

By Ernest A. Le Sueur.

The importance, for certain large applications, of oxygen and of atmospheres rich in that element is being more and more recognized. Strictly pure oxygen will always be relatively expensive because it must be produced by chemical or electrochemical means. It may be separated from air, by various physical methods, of a strength so nearly 100 per cent as to amount to absolute purity for all applications. The yield, however, of such an oxygen (in any physical process) compared with the total mass of oxygen in the air under treatment is so small as to render its cost excessive save for purposes consuming it by the thousands as compared with by the millions of cubic feet.

Not only can oxygen be produced in rich atmospheres at a cost a small fraction of that of substantially pure oxygen, but for all large uses the former is the only condition in which actual application of the oxygen can advantageously be made. Air contains by volume approximately one part of oxygen and four of nitrogen (and argon, etc.), and, in burning, for instance, one ton of coal, we raise at least 10 tons of diluting and useless nitrogen to the full temperature of the flame.

Now, a mixture of oxygen and nitrogen containing but 33⅓ per cent oxygen presents but two parts of nitrogen to one of oxygen, and, for a given oxidation job, throws a nitrogen burden into the reaction of only one-half of what a 4-to-1 mixture does. This is, in fact, the proper way to consider the matter, and it may be pointed out that to change a 20 per cent oxygen air to a 33⅓ per cent one by the direct addition of oxygen it is necessary to add another 20 per cent of oxygen.

An atmosphere containing 33⅓ per cent of oxygen is thus much stronger than might superficially appear, and it is, furthermore, the case that there are very few metallurgical operations to which an oxygen mixture stronger than said percentage could be supplied without producing a temperature beyond the ability of tuyeres, furnace linings, etc., to withstand. An ordinary combustion experiment in 33⅓ per cent oxygen air as compared with the same in ordinary air is of extraordinary brilliancy and might well be supposed by a person unversed in such matters to be occurring in pure oxygen.

So much by way of introduction. The processes with which the writer has had somewhat wide experience are adapted to delivering oxygen of any strength from about 40 per cent to substantially 100 per cent, but, as the latter is relatively expensive and is actually needed for but very restricted consumption, it has seemed well briefly to set out the above considerations. It is obvious that if a process delivering 40 or 50 per cent oxygen is used as a feeder to an application requiring a lower concentration, the necessary strength is readily obtained by suitable injection of air.

The work to which reference is made dates back a long time, as developments in this line go, that is to say, it is 11 years since the writer first produced oxygen (substantially pure

as well as in rich atmospheres) via the liquid condition and using pressures round 2000 lb. per square inch as the instrumentality for the necessary refrigeration. It is over nine years since he prepared rich atmospheres using the pressure of an ordinary mining air compressor, or about 110 lb.

The operativeness of the method in which oxygen is obtained in the process in question depends primarily on the fact, denied by the authorities at the time, that a "fractional condensation" from air *under moderate pressures* directly precipitates a liquid rich in oxygen. The accepted belief prior to the writer's demonstration was based on the work of Prof. James Dewar, of the Royal Institution, who had some four years earlier endeavored to investigate the relative proportions in which oxygen and nitrogen liquefy when a mass of air is exposed to partial liquefaction.

Unfortunately he arranged matters so that the only possible result was a complete liquefaction of a fraction of the air (the residue remaining isolated from the liquefaction compartment and the low temperature thereof) instead of a fractional liquefaction from the whole of it. The erroneous inference was drawn that air, in its first stages of liquefaction, could only deposit a liquid of its own composition, and the conclusion was accepted throughout that section of the scientific world that interested itself in this field of investigation. One result of this was that if a liquid, and subsequently a gas, rich in oxygen was desired to be obtained from air it was considered necessary to liquefy air as a whole and then subject it to fractional distillation.

The old process by which Linde obtained liquids rich in oxygen, which consisted in liquefying a portion of a stream of air by the combined influence of low temperature and enormous pressure and then effecting fractional distillation of a gaseous mixture weak in oxygen by a relief of pressure from 2000 lb. per square inch down to atmospheric pressure, failed to show the incorrectness of Dewar's conclusion because of the further fact, discovered by the writer, that "the higher the pressure under which fractional condensation of liquid occurs from air, the weaker in oxygen is the said condensation."

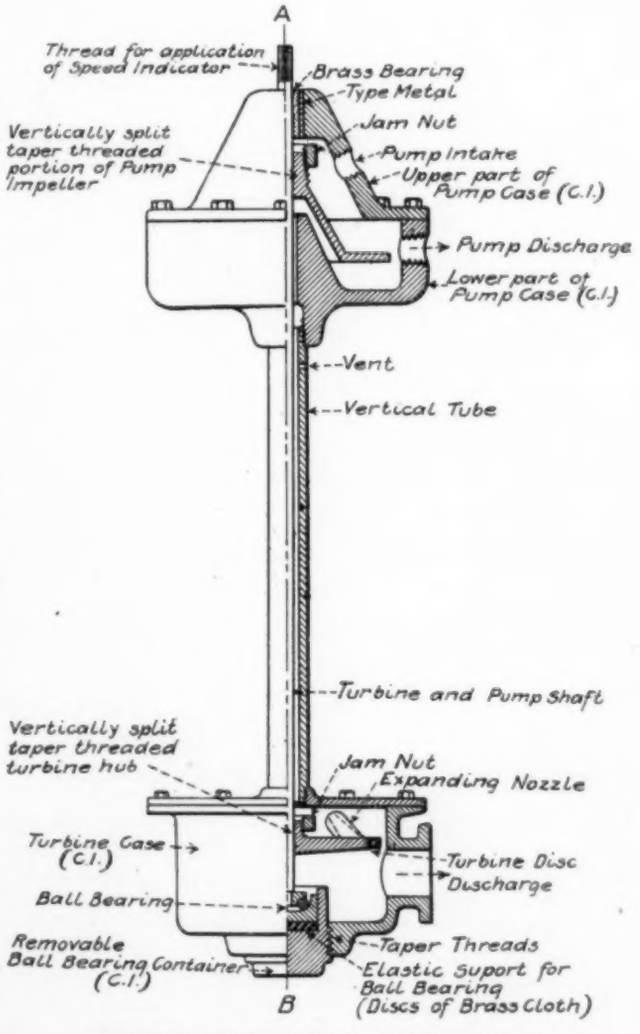
In terms of distillation the inverse holds as follows: "The higher the pressure under which a fractional distillation occurs from a liquid mixture of oxygen and nitrogen, the richer in oxygen is said distillation."

The following experiment made by me in the early days of my work in this field suffices to demonstrate the fact that the condensation, from air which has undergone a partial liquefaction, is much richer than is air. I immersed in a boiling mixture of oxygen and nitrogen much richer in oxygen than is air (and consequently boiling at a decidedly higher temperature than either the boiling or liquefying point of air proper), the lower end of an empty, unstoppered test tube of fairly large diameter (about ⅞ in.). After immersion for some minutes examination showed the tube to contain a small quantity of a decidedly blue liquid, which was found, on analysis, to contain over 40 per cent of oxygen.

The following will indicate the lines along which a cheap and efficient method of preparing fluids rich in oxygen was developed. In the first place, in order to attain anything like efficiency in the use of a gas, such as air (as distinct from a vapor liquefiable by pressure alone, like ammonia), as the working fluid of the refrigerative cycle, it is imperative that the power represented by the drop of pressure of the gas shall be abstracted as far as possible in the act of expansion. This fact has long been recognized, and Sir William Siemens attempted to liquefy air by expanding previously cooled compressed air through an engine. His apparatus was, however, totally inadequate to attain the intensely low temperature required for his purpose.

The apparatus for preparing liquids and gases rich in oxygen depends for its operativeness on the fractional condensation of a liquid rich in oxygen from air and on the development in workable form, first, of a motor adapted to abstract as much as possible of the power of the expanding gaseous residue at the point of lowest temperature, and, secondly, of a form of counter-current thermal interchange apparatus combining moderate cost with high heat interchange efficiency, and having spacious passages for the air on its way down in temperature so that trouble with clogging by aqueous frost at comparatively high temperatures and by solid carbon dioxide at very low ones is avoided.

These last requirements are almost wholly absent from apparatuses intended merely to liquefy air, because, while atmospheric air is the raw material in each case, the volumes treated by an apparatus of a given horse-power for producing atmospheres rich in oxygen are enormously greater (some 40 times) than when liquid air is the product. It was found better on the whole to allow the low temperatures developed in the process to take care of the separation of the final portions of the frost and carbon dioxide than to attempt to remove these materials completely, by any chemical treatment, from the very great volumes of air handled.



APPARATUS FOR ENRICHING AIR WITH OXYGEN.

The first motor developed in this connection (in 1900) was, in general, a de Laval type turbine disk arranged specially for the very peculiar conditions of operation. As might be imagined, the greatest problem in connection with its regular operation was to withdraw its power from it without serious losses of refrigerative effect. This might have been done (and it was originally proposed to do so), by connecting the turbine

to an electrical generator, but for various reasons a direct-connected rotary water pump was employed.

The turbine worked near the lower extremity of a vertical shaft, supported beneath on a ball bearing, in a casing from which the intensely cold exhaust (a mixture of gases rich in nitrogen and of liquid rich in oxygen) was discharged. The compressed air (pre-cooled by its course down in temperature through one set of passages in the thermal counter-current system) was admitted to the turbine guides through one of more expanding nozzles.

The shaft extended some 2 ft. vertically from the turbine case through a steel tube which enclosed it with but little clearance up to the pump casing. The pump impeller was an absolutely smooth disk (if disk it may be called in view of the shape shown in the figure) of but 4⅝ in. diameter, and the high speed of rotation gave a pressure equal to a head over 30 ft. of water.

The water was prevented from running down the vertical tube aforesaid, when the machine was idle and centrifugal force consequently not operating to drive the liquid toward the periphery of the casing, by an extension of the said tube inside the peculiarly shaped impeller. The whole arrangement is illustrated in the illustration. The water was pumped round and round, past a throttling valve, through a coil immersed in a calorimeter tank, and, as all the energy of the pump was thus transformed into heat, it was an easy matter to measure the rate at which heat was being withdrawn from the working fluid.

We thus had hot water circulating in the upper portion of the machine and cold fluids in the lower portion. With a view to preventing water vapor from finding its way down the vertical tube and freezing things up solid, an extremely small vent was provided in the upper part of said tube through which a gradual stream of cold gas from the turbine case continually passed, being driven by the slight residual pressure existing in said case and which arose from the back pressure in the pipes and passages leading the exhaust upwards in temperature. Any sudden drop in the performance of the turbine was instantly evident on the pressure of a gage attached to the pump.

In dropping the temperature of the apparatus preparatory to an oxygen run things would go smoothly down to a temperature well below that at which the apparatus could be run for liquid air in the method hereafter described, and then, all of a sudden, the turbine nozzle would start to plug with solid carbon dioxide. Save that we circumvented this by the operation described below, we could never have got the temperature any lower because we could not continue to withdraw energy (heat) from the working fluid.

The way I got over this obstacle was as follows: As soon as the nozzles plugged the supply of intensely cold compressed air was shut off and a current of relatively warm compressed air (about 75° below zero C.) was shunted in for a few seconds from a point part way down in temperature on the counter-current system. This almost instantly caused the solid carbon dioxide to vanish and we then shut down the compressor and turbine for a few minutes while we opened a valve leading from the exterior to the exhaust pipe of the turbine and poured through said valve some 30 gal. of a liquid mixture of oxygen and nitrogen.

On closing the valve and starting up again the chilling effect of this "priming charge" sufficed to carry the temperature of the turbine feed below the point at which trouble could occur in the nozzles from CO_2. The fractionating of the air into fluids respectively rich and poor in oxygen then commenced and proceeded. The liquid portion (rich in oxygen) was delivered (with or without further concentration) to the low temperature end of one of the three sets of passages of the counter-current system and the gaseous portion, or portions, delivered to a second set of passages. The remaining (intermediate) set of passages was, of course, utilized by the down-flowing current of compressed air.

The final result was a discharge from the high-temperature ends of the counter-current passages of gaseous mixtures respectively rich and poor in oxygen, the temperatures as they finally left the system being about 10° C. lower than when (as a single current of compressed air) they entered it. The oxygen runs, as we called the above, required about eight times as long to get the apparatus properly chilled off as the liquid runs, and we succeeded in making these latter many months before the apparatus had been perfected sufficiently to make the former.

For making liquid we simply ran the exhaust of the turbine through a lagged galvanized-iron drum about 16 in. diameter by 4 ft. long, containing a coil of *lead* pipe to which air, compressed by a small auxiliary compressor to about 400 lb. or 500 lb., was admitted. This air readily liquefied. In these liquid runs the efficiency of the main heat interchange was remarkably high, only about 2° difference being observed between the temperatures of the inflowing and outflowing fluids.

The reason we had the trouble with solid CO_2 at the excessively low temperature we did (just at the point at which the air was preparing to deposit a liquid condensation rich in oxygen) was because, in spite of the fact that carbon dioxide freezes at about—56°, its partial pressure, as it exists in air, is so excessively slight that it does not make its appearance until around 100° below its freezing point.

While there is very much to be said in favor of the turbine type of motor for this purpose, especially should the instrument be built by experts in de Laval construction, I nevertheless have to consider much of the above of historical interest only because I was successful later in operating a specially built "steam engine" on the mixture of liquid and gaseous constituents of air (exhausting at about 300° below zero Fahr., and incidentally leaking a little liquid oxygen at the metallic packing at the piston gland).

This apparatus, when in operation, was a sight worth seeing because the engine was surrounded by a mist and by wreaths apparently of vapor, exactly like a steam engine with a little steam blowing off, but the reason was the condensation, out of the air in contact with such parts of the engine as were unavoidably exposed without lagging, of the contained moisture as frost, with the steamy aspect familiar to all those who have worked with these intensely low temperatures.

Using the engine the trouble with CO_2 completely vanished. The power was taken off a belt-connected Westinghouse direct-current generator, and the instrument readings on same gave a continuous indication of the progress of the energy (heat) abstraction.

The results obtained fully justify the statement that, on a large scale and with cheap power, the total gross costs of the oxygen contents in a 40 per cent to 50 per cent rich atmosphere would be about 14 cents per 1000 cu. ft. While, in order to secure this figure, a production not far from 1,000,000 cu. ft. is required per 24 hours, there are many metallurgical and chemical applications requiring oxygen to which taking care of this amount would be a small matter. The plant is simple in construction and liable to but slight repair cost, which latter are included, together with interest, in the above estimate of product cost.

An experiment of some interest was tried when working on the turbine which consisted in the employment of a frozen mercury bearing for the turbine shaft. Obviously no lubrication was possible at the low-temperature end and the frozen mercury was an ideal anti-friction metal so far as the coefficient of friction was concerned. But it was too utterly soft in wearing qualities, even at very low temperatures, to give satisfaction.

I may mention that I relied almost entirely on cotton batting as a heat insulator. For special purposes, requiring a covering susceptible of being used as a plaster, a mixture of roofing tar and hair gave what were considered surprisingly good insulating properties, considering its lack of cellular character. I

may also put up a good word for lead, both in sheet and pipe, for low-temperature work. In important parts of the plant its use made practicable a form of construction which I regard as almost indispensable.

A good form of storage for liquid mixtures of oxygen and nitrogen consisted in what I called the "wasp's nest" container. It was composed of a cylindrical galvanized-iron holder, with cone-shaped top and bottom, well lagged with about 4 in. of cotton batting contained in an outer casing of tin or light galvanized iron, and then another 4 in. of batting and a final outer container. The lagging covered practically only the sides and bottom of the holder and the whole arrangement was supported by being hung by ropes from the ceiling, there being thus no props from beneath to conduct the heat into the liquid charge.

It is of interest to note that the value of the oxygen in a 50 per cent mixture as compared with pure oxygen for applications requiring a strength not greater than 50 per cent, is 0.74. That is to say, 74 parts of pure oxygen added to 126 parts of air (costing nothing) give 100 parts total oxygen in a 50 per cent mixture.

OTTAWA, ONT., CANADA.

Defects in Refractory Brick and Their Causes.

BY GILBERT RIGG.

Some time ago a friend of mine was trying to buy firebrick for a special purpose. His efforts to obtain suitable material were, to put it mildly, only moderately successful. To quote his own words, "What with the furnaceman's prejudices, the firebrick salesman's optimism, my own ideas, and the actual results, I am having a delightful time."

I am inclined to believe, judging from my own, that my friend's experience is by no means unique. The four indeterminates quoted above need to have fixed and definite values substituted for them. By bringing the first term to zero, substituting for the second set of specifications directly correlated to the third, and for the third a knowledge of the chemical and physical conditions under which bricks required for a given purpose must work, we obtain three new values by which the fourth, or the actual results, may be determined in a manner to give satisfaction to the consumer.

M. Baraduc-Muller, assistant to M. LeChatelier, in an excellent paper read before the Congress of Applied Chemistry, in London, brings a strong indictment against refractory products in general. After making a careful analysis of the factors which go to make first-class goods, which factors he afterwards combines into what he calls a "ceramo-metric coefficient" of value, he sums up the defects of what one frequently finds on the markets as follows:

"The principal defects, which the best of them show when in use, are:

"(1) Insufficient purification of material.

"(2) Methods of manufacture inadequate in mechanical power, superannuated in fact, and inappropriate for the new conditions which have to be met.

"(3) Burning at a temperature much lower than that at which the products will be employed.

"From these errors there results:

"(1) Too low a fusion point.

"(2) A lack of constancy in the dimensions of the pieces during service.

"(3) Want of compactness.

"(4) A porosity too great to resist the destructive action of gases and liquids.

"(5) A mechanical resistance too low to resist the wear of friction and shock.

"(6) Lastly: Much too great a sensitiveness to temperature changes for the prevention of cracks and fissures, which facilitate chemical and mechanical destruction."

This is a somewhat severe indictment, and in many cases, I believe, a well-deserved one. But, to be fair, some trouble arises also from lack of knowledge, on the part of the consumer, of the conditions under which the bricks are to serve. Given that these conditions are known and standarized, then the blame is entirely the manufacturer's, if he fails to meet them.

The term "refractory" is a relative one and covers a wide range of properties. Because a given firebrick does not melt down at the temperature at which it is employed, it is not necessarily refractory. Not infrequently, of two bricks with different fusion points, the one with the lower fusion point may be the more refractory under the conditions of employment.

In a case that has come under my notice, two types of firebrick (A and B) have been employed for the same purpose. A is less resistant to temperature than B, but resistant enough to withstand any temperature that can arise under working conditions. Still, if a cone test were all that was concerned, B would be classed as the better brick.

And yet A lasts five times as long as B.

The reason is not far to seek. On breaking a specimen of A we have a dense stony mass, the fracture passing through the grains of grog, which are welded into a solid mass with a bond. A broken surface of B shows the body of the brick to be a more or less crumbling mass, the grains of grog sticking out like loose teeth, and ready to fall out at a touch. Although the outside looks good, the inside is penetrated by a network of interlacing cracks.

Under working conditions A slowly wears away from the surface inwards. B falls to pieces. And B is typical of a large percentage of the so-called refractory bricks on the market. Lack of care in sizing the grog (the bricks in question contained "chunks" ½ in. in diameter), and insufficient temperature in burning, are the cause of the trouble in this case. The clay is right. The bricks are hopelessly wrong.

The properties possessed by a product which may properly be spoken of as refractory may include any or all of the following according to the conditions of service:

(1) Absolute infusibility at the highest working temperature.

(2) Complete absence of deformation and shrinkage under working conditions.

(3) Mechanical strength.

(4) Complete resistance to penetration of vapors, slags, etc.

(5) A chemical composition fitted to withstand as perfectly as possible the corrosive action of the substances to which the bricks are exposed.

(6) Equality and fixity of form and dimensions.

Let us consider these points in some detail.

A truly refractory product should be infusible at the temperature of service, not only as a whole, but as regards every part of it. A brick cannot be considered as really infusible which retains its general rectangular outline, and yet shows deep pits and slaggy patches due to particles of pyrite and other fluxes. A truly refractory product must be uniform in composition, and that composition must correspond to a melting point substantially higher than the temperature of service. Both the bond clay and the grog must conform to this condition. Very frequently they do not.

Deformation and shrinkage may be due to a wide range of factors which may be classified under two heads, composition, and temperature and duration of burning, the first set controlling the second.

The temperature at which the burning of the goods is carried out must be such as to ensure that the shrinkage has reached a maximum for the temperature of employment; the same thing applies to the duration of the burning. The readjustment in the relative position of the molecules, or particles of clay, which takes place at high temperature, requires time for its completion, different clays requiring different times. With a mixture of two clays, one high in silica, the other high in alumina, the mass burned at 1000° C. for 24 hours, had a breaking strain of

240 lb. per square inch. After seven days at the same temperature, the breaking strain was 534 lb. per square inch. The breaking strain is substantially a measure of the density and compactness of the mass.

Further, the material must be such that deformation (by softening or irregular shrinkage) does not occur. When a body of new masonry is heated, it expands. If the original burning of the bricks has not been carried out long enough, or at a temperature sufficiently high, shrinkage will supervene after the work has reached the maximum temperature, with formation of cracks and other troubles. The consumer should, therefore, know what is the maximum temperature the bricks must stand, and the manufacturers should be in a position to know at what temperature to burn his goods to ensure them against shrinkage, and what materials to use to ensure them against deformation at the temperature in question.

Under the head of deformation I include not only change of form as a whole, but also change of internal form or separation of constituent grains, giving rise to disintegration and crumbling.

A brick of high infusibility, burned at a temperature too low to ensure dense burning, and employed at a temperature too low to develop density, may not shrink seriously as a whole, but, being mechanically weak, will frequently crumble and disintegrate. Such a brick will be inferior under working temperature conditions to one more fusible and burnt dense, if the fusibility is not so great as to cause softening when in service.

The question of density is of tremendous importance in relation to the question of penetrating vapors and slags.

Whenever firebricks are to be exposed to these exceedingly destructive influences they should be burned at a temperature at which porosity is as nearly as possible zero.

The extent to which some slags will penetrate into the pores of a brick is remarkable and the effect is often disastrous. Under the microscope the pores of such bricks are seen to be filled with slag, even when the appearance to the naked eye will show nothing unusual. Comparison of a "penetrated" brick with a fresh one, at high temperatures, may indicate several hundred degrees difference in the fusion point. To quote a case from my own experience, the melting point of a fireclay mass exposed to a penetrating slag fell from over 1700° C. to 1400° C., although, except for a coat of glaze, it appeared unchanged. Under the microscope the filling of the pores by slag was plainly visible.

It is entirely illogical to go to the expense of the highest class of refractory clay to manufacture a porous product whose fusibility is bound to increase enormously under working conditions.

In dealing with this question the maximum temperature of service should be known, and the manufacturer must arrange his mixture to withstand this and burn the brick at a temperature that will reduce its porosity as nearly as possible to zero. Under these conditions the attack of the slag will be from the surface only, and the life of the brick will be greatly prolonged.

This brings us to the fifth item, or the relation of the chemical composition of the brick to the slag, etc., it must withstand. The necessity for this is obvious and is more or less recognized in connection with furnace linings.

Fixity of form and size is essential in reducing the thickness of the joints to a minimum and facilitating the work of the masons. The joints are always the weakest part of the work, as in the nature of things the mortar must be porous and more or less open in texture. Bad mason work is not always due to the mason. Some of it is due to warped and irregular brick. Moreover, the relining and repairing of a furnace is frequently carried out under hot and trying conditions when the men are not in shape to devote close care and attention to making up for the faults of the brick manufacturer.

One sometimes hears it said that "A's" firm used to turn out a first-class brick for our purpose, but the quality has gone off altogether latterly." Is it quite certain that the quality of the brick has gone off in all cases? Have not changed conditions of service something to do with it? Increase of output on a given metallurgical unit unusally means increase in the severity of the working conditions. Similarly the manufacturer who loses a customer and who feels, nevertheless, that the quality of his product is as good as ever it was, has perhaps failed to recognize that the quality of his product has not kept pace with the demands of service.

Papers like the one quoted above tend to show that all is not well with much of the refractory ware now on the market. It would be interesting to know from those responsible for successful smelting operations how many would be found to curse and how many to bless? My own experience is that there is often cause for the former.

New Jersey Zinc Company.

Furnace Electrode Losses.

At the Charlotte meeting of the American Institute of Electrical Engineers, held from March 30 to April 1, two papers on furnace electrode losses were presented, the authors being Mr. Carl Hering and Dr. A. E. Kennelly. Both papers are printed in full in the March issue of the *Proceedings* of the Institute.

The paper of Mr. Carl Hering is entitled "The Proportioning of Electrodes for Furnaces." Mr. Hering explains that his investigation applies to "the electrode proper, or what might be termed the essential electrode, or the chief part of an electrode, namely the part which passes through the walls, and in which the co-operation of the two heat flows is the governing feature. Any additional parts within the furnace or projecting beyond the outside of the walls are not theoretically essential parts, even though they may be very necessary in practice; such parts are evidently determined by entirely different conditions and considerations and must be treated apart from that portion which is absolutely necessary to lead the current from the outside to the inside of the furnace. To attempt to combine the various parts of such a longer electrode and to treat them as one in an analysis for finding out the laws governing the proportions would either be impossible or would, at least, lead to endless complications rather than to a simplification." Hence, throughout the paper the proportions of the electrode, and particularly the length, refer to this essential part passing through the wall. The heat insulation of the essential part of the electrode from the surrounding walls is assumed to be perfect.

Mr. Hering sums up the results of his analysis and introduces two quantities as "true and correct measures of excellence" of materials for use as electrodes. These are the "electrode voltage" and the "specific section." They are constants for the particular materials, in so far as they are independent of the dimensions. The former concerns the power loss and the latter the size. The lower their values are the better is the material for electrodes.

Electrode Voltage.—For every material there is a fixed and definite voltage for 1° which voltage is the same no matter what the size of the electrode or the normal current, provided only that the electrode is correctly proportioned so that no heat flows through the hot end in either direction, the hot electrode end acting as a perfect heat value. This electrode voltage e in volts is

$$e = \sqrt{2kr}$$

if k is the thermal conductivity in watt, inch cube units, and r the electric resistivity in ohm, inch cube units, and k as well as r are assumed to have the same values over the whole length of the electrode. The total voltage E between the hot and cold electrode ends is then

$$E = \sqrt{2krT} = e\sqrt{T}$$

where T is the temperature drop in centigrade degrees between the hot and cold ends. E multiplied by the current in amperes gives the minimum loss in watts which can possibly be obtained

with that material, for that current and temperature. On this account Mr. Hering calls E the "watts per ampere."

Specific Section.—Under the same assumption that r and k have the same values over the whole length, the relation

$$S = IL\sqrt{r \div 2kT}$$

exists between the electrode cross-section S in square inches, the electrode length L in inches ("essential length"), the current I in amperes and the temperature drop T in degrees C.

If I, L and T are made unity, that is, for 1 amp, 1 in. length and 1° C. of temperature, the resulting cross-section, now represented by s, becomes

$$s = \sqrt{r \div 2k}$$

This is called the "specific section." This is for 1° C., while for the temperature drop T, there is

$$S' = s \div \sqrt{T} = \sqrt{r \div 2kT},$$

which, since $S' = S \div IL$, is called the "section per ampere per inch length." By multiplying S' with the current and the length, the actual cross-section is obtained, for which the electrode is correctly proportioned so that the hot electrode end acts as a perfect heat valve.

Temperature Cent. degrees	Temperature Fahr. degrees	E Watts per ampere				S' Square inches per-ampere per inch length				S' Square centimeters per ampere per cm. length			
		Carbon	Graphite	Iron	Copper	Carbon	Graphite	Iron	Copper	Carbon	Graphite	Iron	Copper
400	752	1.00	0.85	0.145	0.095	0.00165	0.00040	0.000103	0.000016	0.0042	0.00100	0.00026	0.000041
600	1112	1.38	1.04	0.225	0.140	0.00114	0.00031	0.000102	0.000015	0.0029	0.00078	0.00026	0.000037
800	1472	1.68	1.19	0.295	0.184	0.00090	0.00027	0.000101	0.000014	0.0023	0.00068	0.00026	0.000036
1000	1832	1.93	1.32	0.350	0.226	0.00076	0.00024	0.000098	0.000014	0.0020	0.00061	0.00025	0.000036
1200	2192	2.15	1.43	0.410	0.270	0.00069	0.00022	0.000094	0.000014	0.0018	0.00056	0.00024	0.000035
1400	2552	2.36	1.52	0.460	0.310	0.00062	0.00020	0.000092	0.000014	0.0016	0.00051	0.00023	0.000035
1600	2912	2.53	1.62	0.510	0.351	0.00057	0.00019	0.000089	0.000014	0.0014	0.00048	0.00023	0.000035
1800	3272	2.68	1.71	0.565	0.391	0.00053	0.00018	0.000087	0.000014	0.0013	0.00046	0.00022	0.000035
2000	3632	2.83	1.79	0.610	0.430	0.00049	0.00017	0.000085	0.000014	0.0012	0.00044	0.00021	0.000035

Experimental Results.—The experimental determinations were made by the method described in Mr. Hering's Am. Electrochem. Soc'y paper (our Vol. VII, page 514). The main results are given in the following table and diagrams. The full lines in the curve sheets represent the ranges over which the results were actually measured; the dotted lines are exterpolated and "therefore, are only probable values." "There may, of course, be radical changes in these physical constants at the melting points of the metals, and at some points at which carbon may change its condition. These cannot be predicted. The present extensions are all based on a regular continuation of the measured relations."

The curves for the electrode voltage and the specific section are given in Figs. 1 and 2. In Fig. 1 they have been drawn to different scales so that they are nearly superimposed, thus enabling their relative inclinations or percentage values to be compared better with each other, while in Fig. 2 they have all been drawn to the same scale, so that they may be compared quantatively.

In Fig. 1 the curves E, which measure the minimum loss, or the watts per ampere, all have a family resemblance, except in the case of graphite. The marked difference of the graphite curve means that the losses in graphite electrodes do not grow as rapidly with the temperatures as they do for all the other materials. This, of course, is a very good quality, especially for high-temperature furnaces. For all the others the relative increase of this loss is about the same.

A comparison of the same curves E, in Fig. 2 (the heavy line curves) shows the quantitative relations of the actual losses per ampere. The much greater loss for carbon is quite striking; but, of course, there are many cases in which metals are excluded by the very nature of the furnace.

The loss for carbon is seen to be 1.55 times that for graphite.

If the current and temperature drop are given, and if the essential length is taken as the thickness of the furnace walls, the section in square inches is then determined at once by multiplying the proper temperature value of S' from the above table by the current in amperes and by the length in inches. If this is too large or too small to be practicable, the length may be changed and the section may be redetermined. The quotient of the section divided by the length is a constant for any specified conditions (numerically equal to S' from the table multiplied by the current), hence they may both be increased or decreased in the same proportion.

The loss in the electrode in watts is entirely independent of the section or length adopted, provided only that their quotient is approximately as above. It is calculated in watts by multiplying the corresponding temperature value of E in the above table by the current.

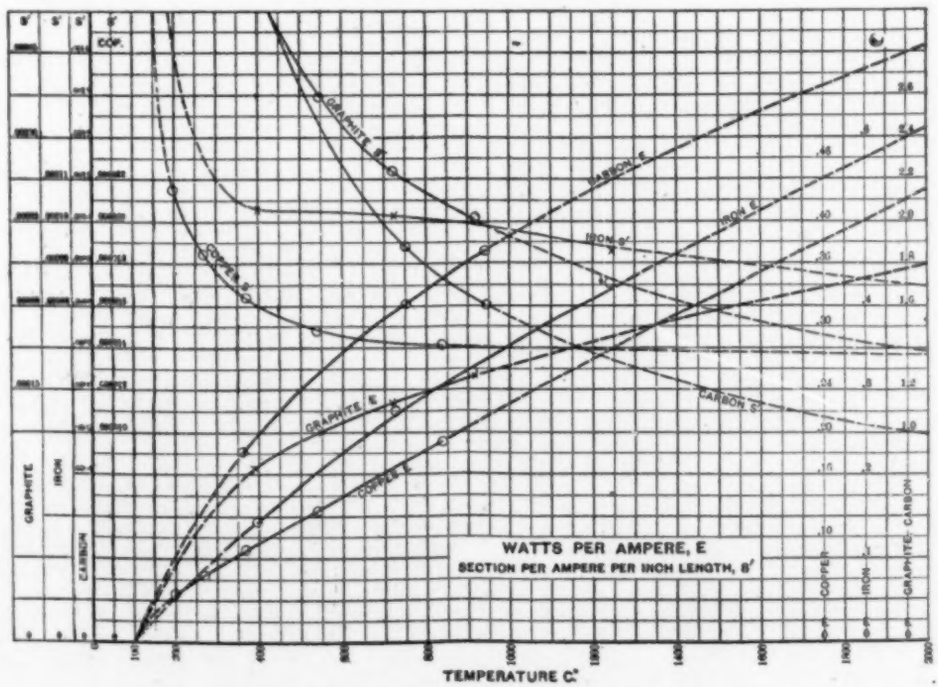


FIG. 1.—LOSSES AND SIZES. (SUPERIMPOSED.)

* * *

The paper by Dr. A. E. KENNELLY deals with the "modifications in Hering's laws of furnace electrodes introduced by including variations in electric and thermal resistivity."

The assumption made by Dr. Kennelly concerning these variations is that both resistivities are linear functions of the distance from the hot electrode end. Under this assumption the integration of the fundamental differential equation leads to comparatively simple formulas, which lend themselves readily to numerical applications.

Two numerical examples are given.

The general results arrived at are summed up by Dr. Kennelly as follows:

1. The combined loss through the cold end of an electrode is equivalent to the sum of the loss by heat conduction alone (when there is no current) and approximately half the I^2R loss, the exact fraction depending on the temperature coefficients of the resistivities. With constant resistivities, the fraction will be one-half.

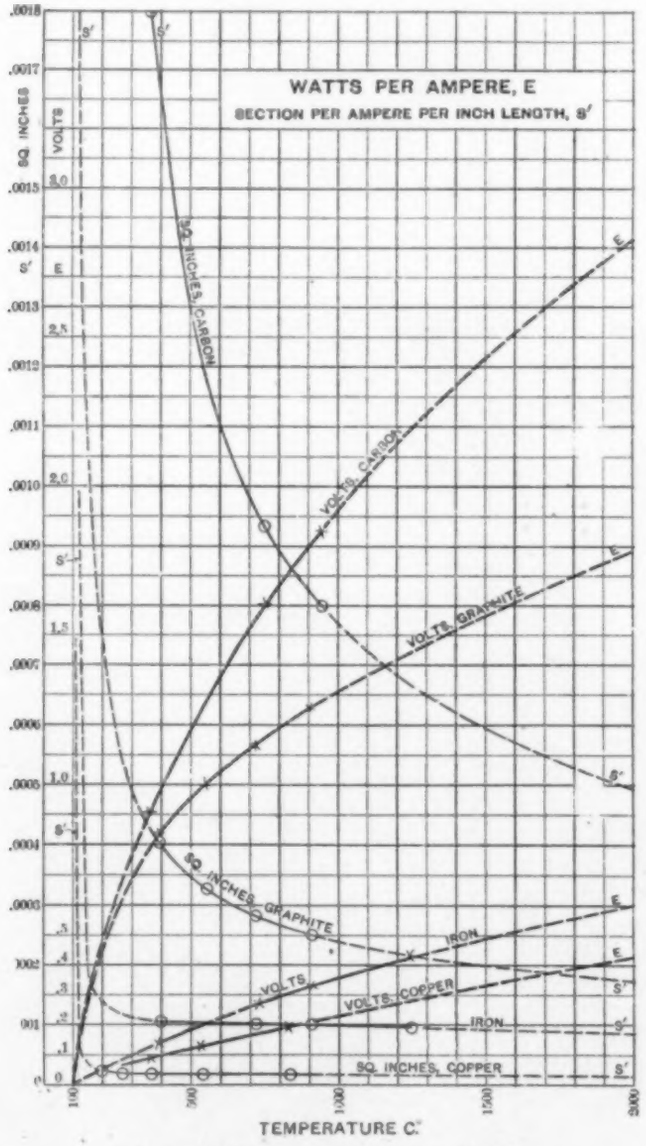


FIG. 2.—LOSSES AND SIZES (SAME SCALE).

2. The above combined loss will be least when the loss by heat conduction alone is equal to the Joulean loss through the cold end.

The total loss will then be approximately equal to the total Joulean loss, and very little heat will flow into or out of the furnace.

With constant resistivities, this resultant furnace flow will be nil.

Chemical Reactions at Electrodes.*

By Reston Stevenson, Ph.D.

The following article is merely a review of the broad field of electrochemical reactions in liquid solutions and more particularly in aqueous solutions. It is in no way a presentation of new experimental research or of new theories. The writer wishes to acknowledge his indebtedness to Dr. Bancroft, of Cornell, and to Dr. Turrentine, of Wesleyan University, for suggestions and references, and to Dr. Baskerville, of the College of the City of New York, for assistance in the preparation of this paper.

In electrochemical reactions, the ions are carried to the respective electrodes, where they lose their charge and react with whatever is at hand. Obviously the nature of the ions originally in the electrolyte is of prime importance. This consideration is complicated by the fact that ionization is not always of the simple sort, such as $NaCl = Na + Cl$, but sometimes double ionic natures are displayed.

For example, Br in liquid sulphur dioxide gives upon electrolysis Br at both the anode and the cathode. Similarly, I in sulphuryl chloride gives I at both electrodes. In the electrolysis of an alkali solution with tellurium electrodes, Te'' is formed at the anode and $Te^{\cdots}$ at the cathode. $Pb(OH)_2$ may ionize in any of these ways:

$$= PbOH^{\cdot} + OH'$$
$$= Pb^{\cdot\cdot} + 2\,OH'$$
$$= H^{\cdot} + PbOOH'$$
$$= 2\,H^{\cdot} + PbO_2''$$

In an acid solution the ionic product of H_2O is exceeded and, therefore, the OH ions practically disappear, so that we have only Pb and OH ions.

In an alkaline solution, the ionic product of H_2O is again exceeded and causes the practical disappearance of the H ions so that we have only PbO_2 and OH ions in the solution.

Glycocoll dissociates thus:

$$HOH_2NCH_2COOH = H_2NCH_2C{\cdot}O'O + H^{\cdot} + OH'.$$

Of course the two dissimilar charges upon the residue neutralize each other, leaving H and OH ions in the solution.

When the electrolyte is not a single substance in solution, then the relative amounts of the different ions which are carried to the electrodes to react, depend upon the migration velocities of these different ions. Electrolytes are ionized quite differently according to the solvents[1] which are used, sometimes showing association instead of dissociation, etc.

Not only may there be a variety of ions in an electrolyte, but these ions may react in various ways at the electrodes and many of these reactions may occur simultaneously. For example, in the electrolysis of NaCl solutions, we may obtain NaOH, Cl, NaCl, NaClO, $NaClO_3$, $NaClO_4$ and O_2.

As a review of the field of electrochemical reactions, we will classify all of the various reactions which have occurred at electrodes, and then consider the variable factors concerned in the equilibrium of these reactions. The following reactions occur at electrodes:

1. The discharged ion reacts with itself.
2. The discharged ion dissolves in the electrode.
3. The discharged ion reacts with the electrode.
4. The discharged ion dissolves in the solution.
5. The discharged ion reacts with the solvent.
6. The discharged ion reacts with the solute.
7. The discharged ion reacts with suspended particles.
8. The discharged ion reacts with dissimilar ions of similar charge.
9. The discharged ions of dissimilar charge react with each other.
10. The reaction products which are at first formed, break down and form secondary products.

* An address delivered before the New York Section of the American Electrochemical Society on March 16, 1910.

[1] Le Blanc, Whitney and Brown: Electrochemistry, p. 142.

11. The products at the electrodes diffuse and react away from the electrodes.

12. Electrolysis with alternating current.

13. Electric endosmose.

14. Electrostenolysis.

15. Reversed electrolysis.

1. **The Discharged Ion Reacts with Itself.**

Examples at the cathode are:

$$H' + H' = H_2$$
$$Cu'' + nCu'' = Cu_{n+1}$$

At the anode:

$$O'' + O'' = O_2$$

2. **The Discharged Ion Dissolves in the Electrode.**

For instance Na forms sodium amalgam with a cathode of Hg; H dissolves in a cathode of Pd; O dissolves in an anode of platinized platinum.

3. **The Discharged Ion Reacts with the Electrode.**

Cathode: Na forms an alloy with a cathode of Pb. Zn plated on Pt may alloy to a slight extent.

$$2H' + PbO_2 + H_2SO_4 = PbSO_4 + 2H_2O$$

Anode:

$$O'' + PbSO_4 + H_2O = PbO_2 + H_2SO_4$$
$$3Cl' + Fe = FeCl_3$$
$$4O'' + CuS = CuSO_4$$

In the electro-analysis of halides, phosphates, etc., a silver anode is used and the corresponding compounds are formed and adhere to the anode and can be weighed.[3]

4. **The Discharged Ion Dissolves in the Solution.**

At the cathode the solution is saturated with hydrogen and, at the anode, with chlorine, bromine, etc. The substances may be dissolved either in the solute or in the solvent.

5. **The Discharged Ion Reacts with the Solvent.**

Cathode:

$$Na' + H_2O = NaOH + H$$
$$Ca'' + 2H_2O = Ca(OH)_2 + H_2$$

Anode:

$$SO_4'' + H_2O = H_2SO_4 + O$$
$$2CH_3COO'' + H_2O = 2CH_3COOH + O$$

6. **The Discharged Ion Reacts with the Solute.**

Cathode:

$$H' + FeCl_3 = FeCl_2 + HCl$$
$$Al''' + 3HCl = AlCl_3 + 3H$$

Anode:

$$Cl_2(SO_4)_2 + 3H_2O + 3O'' = 3H_2SO_4 + 2HClO_4$$
$$C_2H_5OH + 10I' + H_2O = CHI_3 + CO_2 + 7HI$$

7. **The Discharged Ion Reacts with Suspended Particles.**

Cathode:

$$C_6H_5NO_2 + 6H' = C_6H_5NH_2 + 2H_2O$$

Anode:

$$C_6H_6 + 2O'' = C_6H_4(OH)_2$$

8. **The Discharged Ion Reacts with Dissimilar Ions of Similar Charge.**

At the cathode Hg and Ag can be deposited as an amalgam from acid solutions. Zn and Cu are deposited as brass from aqueous KCN solutions. In platinizing electrodes, an alloy of Pb and Pt is deposited and the Pb is dissolved away, leaving the Pt in finely divided form. In the plating of Ni, an alloying with NH_4 is often the cause of the peeling of the plate.

At the anode, Cl and O combine to form ClO′ or ClO′₃.

9. **The Discharged Ions of Dissimilar Charge React with Each Other.**

This necessitates that the anode and cathode be very near each other. This would be of practical disadvantage in any electrochemical process.

10. **The Reaction Products Which Are at First Formed Break Down and Form Secondary Products.**

In the electrolysis of NaCl aq. with a Pb cathode, the alloy is formed and then the Na reacts with the H_2O and leaves the Pb as a fine suspension in the solution.

[3] Smith: Electro-analysis, p. 296.

With a Cd anode in a $Na_2S_2O_3$ solution, there is formed CdS_2O_3, which reacts thus:

$$CdS_2O_3 + H_2O = CdS + H_2SO_4$$

11. **The Products at the Electrodes Diffuse and React Away from the Electrodes.**

In the preparation of NaClO, the NaOH at the cathode meets the Cl from the anode and forms the hypochlorite. In the electrolytic preparation of $PbCrO_4$, the electrolyte consists of $NaNO_3$ and K_2CrO_4. The NO_3 attacks the Pb electrode and the $Pb(NO_3)_2$ reacts with the K_2CrO_4 to form $PbCrO_4$ away from the electrodes. In the production of Scheele's green, the electrolysis of Na_2SO_4 yields Na and SO_4 ions. With the Cu anode, $CuSo_4$ is formed. At the cathode, NaOH is formed, which reacts with the As_2O_3 around the cathode, to form Na_2AsO_3. The anode and cathode products diffuse and react to form Cu_2HAsO_3.

12. **Electrolysis with Alternating Current.**

In the application of the alternating current to a reversible cell such as Cu — $CuSO_4$ — Cu, then the same amount of Cu is dissolved at either electrode with the current in one direction as is deposited by the reversed pulsation. The Cu goes into solution and precipitates with practically equal ease. If, however, the Cu electrodes are in a KCN solution then the Cu which dissolves forms a compound with KCN which has only very few Cu ions. From this solution, the Cu is precipitated with much greater difficulty than it dissolves, so that with the alternating current, the Cu dissolves by a zig-zag movement in which the zig is always longer than the zag. In a 4 normal solution of KCN, 75 per cent Cu is dissolved when there are 10,000 alternations per minute, 55 per cent with 20,000 alternations, and 40 per cent with 300,000 alternations. Zn and Ni also dissolve in KCN solutions with alternating current. Ag is practically insoluble in KCN solutions when the alternations exceed 4000 per minute.

13. **Electrical Endosmose.**

Consider a liquid in contact with a solid, such as the glass walls of a capillary tube, or solid colloidal particles of Au, Pt, $Cr(OH)_3$ dyes, such as indigo, methyl violet, etc. Upon these bodies, in contact and moving past one another, are dissimilar charges of electricity. Upon that body which has the greater dielectric constant (usually water), there is a positive charge, and there is a negative charge upon the other body. Therefore, upon passing a current there is a separation at the different poles. When the solid is fixed stationary, e. g., glass tube, wood, etc., then the water alone moves to the cathode.

14. **Electro-stenolysis.**

Consider a salt solution in a beaker and in a test tube which stands in the beaker. The test tube is cracked, so that the two solutions are separated by capillaries. An electrode is in each vessel. Upon passing a current, water goes (c.f. 13) to the cathode and the capillaries are left negatively charged. Therefore positive ions of metal are deposited in these capillaries, but the amount of metal is microscopic because of the large charge on an ion and the small charge on the glass. However, the amount of metal becomes noticeable when it takes part in the conduction of the current and does not dissolve at its anodic end. Such a condition is obtained with the platinum metals and with metals which form insoluble oxides at the anode, such as Co.

15. **Reversed Electrolysis.**[4]

At the cathode occurs reduction and at the anode oxidation, but the apparent action at these respective electrodes may be reversed. This occurs when the reduction product at the cathode is an active oxidizing agent. When a dilute solution of HNO_3 containing KI is electrolyzed with Pt electrodes, the HNO_3 is reduced to HNO_2 at the cathode. The HNO_3 oxidizes the KI setting iodine free at the cathode. In the electrolysis of a solution of $KMnO_4 + H_2SO_4$, with Pt electrodes, the

[3] Le Blanc, Whitney and Brown, Electrochemistry, p. 157.
[4] Turrentine, Trans. Am. El. Soc., 1908, Vol. 13, p. 281.

$KMnO_4$ is reduced to MnO_2 at the cathode with a simultaneous evolution of oxygen at the cathode. Probably the $KMnO_4$ is reduced to Mn_2O_3, which spontaneously reduces to MnO_2 with the evolution of oxygen.

Upon electrolysis of Fehling's solution between Pt electrodes the tartaric acid at the anode is oxidized to formic acid which reduces the cupric salt with the deposition of cuprous oxide on the anode. Upon the electrolysis of a solution of $AuCl_3$ in methyl alcohol with Pt electrodes, at the anode the alcohol is oxidized to formaldehyde which reduces the $AuCl_3$ and causes the deposition of Au upon the anode. Upon electrolysis of a solution of Na_2SO_4 with a Mg anode, the Mg is oxidized to $MgSO_4$ which reacts with the water to set free hydrogen at the anode.

Of these reactions, the nature, direction, extent and velocity may be affected by the following variable factors of equilibrium: temperature, pressure, concentration and nature of electrolyte, current density, light, diffusion, e.m.f., nature and concentration of electrodes, and catalytic action. In any one reaction many or all of these factors might change so that the effect would be the resultant of many different forces. In the following pages will be considered the effect of the variation of some one of these factors while the others remain constant. These three generalizations apply at the condition of equilibrium: the phase rule, the law of mass action, and the theorem of Le Chatelier.

1. **Temperature.**

In all electrochemical preparations, e. g., iodoform, aniline, etc., there is always a narrow range of temperatures within which the greatest efficiency is obtained. Above 300° Na is deposited from the fused salts, but if the temperature is too high, the Na reacts with the bath and the yield is greatly lowered. Similarly, for Ca, Ba, and Al. In the electrolytic formation of persulphates, percarbonates, perchlorates, etc., the temperature must be kept low because these compounds decompose upon heating. In the electrolysis of an aqueous solution of HCl, when the anode is kept cold, chlorine hydrate is formed in crystals. In the electrolytic preparation of NaClO, increased temperature causes the formation of chlorate.

In general, the increase of temperature causes the increase of the diffusion of the electrode products, the velocity of migration of ions, the dissociation of the electrolyte, and the speed of reaction. That reaction which occurs with an absorption of heat would be promoted by an increase of temperature.

2. **Pressure.**

The effect of pressure is rarely studied in electrochemical reactions. Usually, a large change of pressure accomplishes only a slight variation in the point of equilibrium. In general, it may be said that an increase of pressure would promote that reaction which occurs with a diminution of volume (theorem of Le Chatelier).

3. **Concentration and Nature of Electrolyte.**

Since the reactions at electrodes are usually reactions with the electrolyte, the nature and concentration of the electrolyte is all-important. In reversed electrolysis, it has been seen that the nature of the electrolyte can reverse the apparent action of the electrodes. In the preparation of NaClO, if the solution becomes acid, the free HClO oxidizes the hypochlorite to chlorate. If the NaClO becomes concentrated, it diffuses to the cathode and is reduced. In the electrolysis of $CuSO_4Aq$, in neutral solutions at 100°, Cu_2SO_4 is formed which hydrolyzes and Cu_2O is formed. In concentrated HNO_3 solutions and in very concentrated H_2SO_4 solutions, no Cu is precipated because of the greater rapidity of solution than of precipitation. Similarly, Li is not deposited from water solutions, but is from a pyridine solution which conducts the current and does not dissolve the Li. In the electrolysis of HNO_3, with a Pt anode and a Hg cathode, hydroxylamine is obtained, but if Hg ions are in the solution, NO is obtained (a paste of Hg_2SO_4 on the Hg).

In the electrolysis of a 0.3 normal NaCl solution, without diffusion, 5 per cent of oxygen is obtained. In alkaline solutions, ketones are reduced and in acid solutions are formed pinacones. Al can be deposited from ethyl bromide solutions. In the electrolysis of neutral solutions of $Na_2S_2O_3$ the tetrathionate is formed, but this can be prevented by the presence of $Hg(CN)_2$ or by brucine. Salts of Mn and of Cr are used as carriers in electrolytic oxidation. In electroplating, deposits are finer from dilute than from concentrated solutions, the presence of a colloid makes the crystals finer and the deposits are made pure by the introduction of substances to dissolve any oxide or hydroxide that might be formed: e.g., in plating Zn, H_2SO_4, KOH, NH_4Cl, and KCN are used.

4. **Current Density.**

In electroplating too high a current density makes the deposit go bad, due to an impoverishment of ions and the precipitation of oxide, hydroxide, or basic salt. Deposits are finely crystalline with high current density and coarsely crystalline with low current density. When a current of less than 1 millampere is passed between metal electrodes in distilled water, arborescent crystals are obtained.[5] With Fe as anode in sodium acetate acetic acid solutions, at low current density, ferrous acetate is formed and with high current density Fe is passive. Since current density is proportional to the rate of deposition, Al can be deposited as a metal from $AlCl_3Aq$ with such a current density (0.085 amp per square centimeter) that the rate of solution is less than the rate of precipitation.

A high current density is conducive to low electrode efficiency, because the H or Cl., e.g., which is deposited escapes before it comes into contact with any of the reacting electrolyte. Therefore, in the oxidation of $Cr_2(SO_4)_3$ to CrO_3, and in the preparation of iodoform, the anode is large and the cathode is small. In general, the effect of current density is that of mass action.

5. **Diffusion.**

In the deposition of metals a high current density causes an impoverishment of ions at the cathode and thereby causes the deposit to go bad. This impoverishment is prevented by means of stirring with CO_2, H_2, or with rotating cathode or anode. In the precipitation of Al, Tucker[6] uses a pasty solution of $AlCl_3$, 40°, C.D. = 0.085 amp per square centimeter, and a cathode of brass rotating at 15,000 r.p.m.

In many electrolytic processes the reaction at only one electrode is utilized and the reaction at the other is harmful. In the electrolysis of NaCl to form NaOH the caustic at the cathode is separated from the Cl at the anode by means of a diaphragm of Hg. Diaphragms should be very easily permeable to charged ions and should offer a high resistance to diffusion. In making iodoform, the CHI_3 at the anode is separated from the H at the cathode by means of porous porcelain in order to avoid reduction. In making NaClO, $CaCl_2$ or K_2CrO_4 is added to the electrolyte, giving a precipitate of CaO or $Cr(OH)_3$ at the cathode. This precipitate is a membrane which allows the passage of OH and Na ions, but prevents the diffusion of NaOCl to the cathode.

6. **Light.**[7]

Bancroft has shown that those changes which are produced in compounds by means of light can also be produced electrolytically. "Light is a low-voltage current." Also he has shown that the presence of light may affect the direction of a current of electricity and its incidental reactions. If a ray of light which acts as a reducing agent is allowed to fall upon one pole of an electrolytic cell and there brings about a reduction, we then have that pole functioning as the cathode of the cell, and an electric current flows through the cell from the unilluminated pole to the illuminated pole. AgBr is reduced by light which is rich in violet rays and Ag is set free. If

[5] Comptes Rendus, 130, 325, 1900.
[6] Trans. Am. El. Soc., p. 497, 15, 1908.
[7] Bancroft, *Jour. Phys. Chem.*, 1908, et seq.

AgBr is in close contact with the illuminated pole, Ag is deposited on that pole and it becomes the cathode.

If one AgBr electrode is dipped in erythrosine and then replaced in the KBr solution, the dyed electrode is the anode. These sensitizers are used with actinic cells (1) to intercept those rays of light which tend to work oppositely to that reaction which we wish to induce, and (2) the sensitizer is altered by light and yields a product which tends to accelerate the desired reaction.[8]

7. **E. M. F.**

Unless a certain difference of potential (decomposition voltage) exists between the anode and cathode, there will not be sufficient force to separate the ions. This decomposition voltage varies for different combinations of ions so that by careful regulation of the voltage we can select which ions to deposit. In electroplating, two ions are easily separated if the decomposition voltages of all the ions are exceeded and H has an intermediate decomposition voltage. Frequently it is noticeable when the same products are set free at the electrodes and at the same rate (equal current density), that there is obtained different reduction and oxidation products, varying with the voltage of the current. This voltage does not refer to decomposition voltage on anode or cathode, which varies with the distance apart of the electrodes without a change in the nature of the electrode products. The voltage which seems effective is the absolute voltage measured as the decomposition voltage of the electrode and the standard H electrode.

Alcohol is oxidized to acetaldehyde when the decomposition voltage of the anode and the H electrode is 0.7 volt to 1.0 volt; if a higher voltage is used it is oxidized to acetic acid. The decomposition of HF is higher than of HCl, and, therefore, in the oxidation of $Cr_2(SO_4)_3$, $MnSO_4$ and $CoSO_4$ solutions, by electrolysis, greater oxidation is obtained when HF is present. (Z. A. C., 33, 25, 1903.)

In reducing nitrobenzene with many different metals as cathode, various products and in various proportions are obtained, but the same products, azoxybenzene and aniline, are obtained when the cathode potential is kept constant. (Z. P. C., 47,418, 1904.) At platinum electrodes O_2 is formed at 1.08 volts and ozone is formed at 1.67 volts (voltage between anode and H electrode). At the cathode, reduction depends upon the voltage of the cathode compared to that of a H electrode in the corresponding electrolyte.

Counting the voltage of the cathode in a reversible H cell with platinized Pt electrodes as zero and then the "excess voltages" for the different cathodes are as follows:

Pd	−0.26	volt.
Pt	0.00	"
Fe	+0.03	"
Au	+0.05	"
Ag	+0.07	"
Ni	+0.14	"
Cu	+0.19	"
Al	+0.27	"
Pb	+0.36	"
Hg	+0.44	"

The greater force necessary to set free the H shows that these metals offer less accelerative influence in the change $H + H = H_2$. Therefore, these metals accelerate instead of retarding the actions of the H ion in the order of their excess voltages. The effects of these higher voltages are due in most cases to the specific nature of the electrodes and are probably catalytic effects. (See 8 and 9.)

8. **Nature and Concentration of Electrodes.**

Caffeine is reduced more quickly at a cathode of Hg than of Pb, although both metals possess the same cathode excess potential in pure acid. From nitrobenzene, with Cu cathode and NaOH, aniline is formed. With high current densities $KClO_3$ is only slightly reduced when the cathode is Pt, Pb, Zn, or Ni; moderately reduced with a Co cathode, and strongly reduced when the cathode is wrought iron. PbO_2 anodes oxidize $Cr_2(SO_4)_3$ with 80 per cent efficiency; Pb anodes with very slight efficiency. Aqueous KNO_3 is reduced 76 per cent with a Pt cathode, 15 per cent with a platinized Pt cathode and 97 per cent with Fe or Zn cathodes. A cathode of Fe reduces neutral $NaClO_3$ with 23 per cent efficiency, while Zn or Pt cathodes give practically no yield. (Z. E., 7,398.) $HNO_3 + H_2SO_4$ gives 100 per cent NH_2OH with a cathode of Hg, 40 per cent with a Pb cathode and 15 per cent with a Cu cathode. If the Cu cathode is covered with finely divided Cu then no NH_2OH is obtained, but a 100 per cent yield of NH_3 (Z. A. C., 31,289, 1902). If the Hg cathode is covered with Hg_2SO_4, insuring the presence of Hg ions, NO is formed. In the electrolysis of $HNO_3 + H_2SO_4$, if $CuSO_4$ is added, NH_3 is obtained quantitatively, but NH_3 is not obtained if instead of Cu we add Co, Ag, or Cd. When HNO_3 is electrolyzed with a Cu cathode, NH_3 is obtained, but NO is obtained when $Cu(NO_3)_2$ is present at the cathode. (Turrentine, 10,715, 1906.)

To remove brass from Fe tubing the whole is placed as anode in a bath of $NaNO_3$Aq, and the Fe remains passive and the brass dissolves away. (Burgess, *Trans.* Am. El. Soc., 1903, page 31.) To plate Ni upon a surface of Ni, the cathode Ni must first be made active by making it the cathode in another bath (acid solution) for a few minutes before use. (Snowden, J. P. C., 1905, page 399.) Na can be precipitated from aqueous solutions into Hg amalgam because of the slow reaction of Na amalgam with water. Fe and Ni in the amalgam make the reaction with water so rapid that no Na is precipitated.

When the anode is attackable, then the case is complicated by the presence of other compounds in the electrolyte.

9. **Catalytic Action.**

Above 90° cobaltic oxide acts catalytically in the electrolysis of chlorides, setting oxygen free. In 7 and 8 we have noticed that different metals as electrodes have different specific effects in electric reactions and that these effects are obtained without any apparent chemical action on the part of the electrodes. Such influences are probably catalytic. Bancroft[9] has shown that aromatic nitro compounds in acid solution are reduced to amines by Fe, Sn, Pb, and Cu as cathodes or when used chemically; and in alkaline solutions reduced to hydrazo compounds by Sn, Zn, and Pb chemically or electrolytically.

Ostwald[10] has said in regard to catalytic action in electrolysis that an ion first gives up its charge and then occur secondary reactions, and many different secondary reactions may occur.

Catalytic agents may retard some of these reactions and accelerate others.

Conclusion:

In conclusion we may say that reactions at electrodes differ from ordinary reactions in these ways:

(1) Energy is used instead of matter. The amount of substance used in electrochemical reductions and oxidations is small and its active principle is regenerated by electrical energy and used repeatedly.

(2) Localization of effect.

(3) Two dissimilar reactions occur simultaneously.

(4) The regulation of the reaction velocity is easy.

Bancroft has shown the identity of chemical reactions and electrode reactions, and has shown that the same variables affect the equilibrium in both cases. "The only specific action of the electric current is that it tends to set free anions at the anode and cations at the cathode. Reactions occur after the loss of the charge of electricity, and these reactions are ordinary chemical reactions."

Department of Chemistry,
College of the City of New York.

[8] Schleuderberg, *Jour. Phys. Chem.*, 1908.

[9] *Jour. Phys. Chem.*, 1908, p. 120.

[10] *Trans.* Am. El. Chem. Soc., 1904, p. 187.

Can National Professional Societies Be Exclusive and Representative?

The *Mining Magazine*, of London, edited by Mr. T. A. Rickard, prints in its March issue the following editorial, which is entitled "Mining and Metallurgical Society," but has a broader scope and more general interest:

"In April, 1908, the Mining and Metallurgical Society of America was organized, in part as a protest against the nondescript membership of the American Institute of Mining Engineers, and in part to stimulate the discussion of subjects expressly avoided by the Institute, and finally to promote the solidarity of the profession by frequent local meetings. It was intended on the one hand to avoid the duplication of facilities for publishing technical literature and on the other hand to stiffen the moral backbone of the profession by the crystallization of opinion in regard to the ethics and customs of mining engineers, metallurgists and geologists.

"The society started with a nucleus of representative men and at once reached a membership of 100, which on Jan. 1, 1910, had increased to 163, of whom 35 are geologists, 27 are professors, and 4 are editors. The other 97 are active mining and metallurgical practitioners. Of the several geographical divisions of the society formed with a view to local meetings, only two have evinced any life, namely, New York and San Francisco. At Philadelphia one or two small meetings have been held, but the members living near Chicago, Denver, Salt Lake, and similar centers of industry, have failed to organize for purposes of meeting. At New York and San Francisco the attendance has not exceeded an average of a dozen at each monthly meeting.

"Despite the smallness of attendance and the lack of co-operation between the general body of the members, the society has exerted a useful influence by expressing decided opinions in regard to company reports, the duties of consulting engineers, mine inspection, the Bureau of Mines, share speculation, and other matters having a vital bearing upon the business of mining. It is noteworthy that a deputation of the society, headed by the president, recently waited upon the stock-listing committee of the New York Stock Exchange and submitted the resolutions passed—at an earlier meeting of the society—with regard to the protection of mining investors. The resolution, and the members that submitted it, were well received. In another direction the society has also done good work, for the American Mining Congress has been pleased to ask the society to express its opinion and to formulate suggestions in regard to new laws regulating mine inspection.

"Thus it is apparent that the Mining and Metallurgical Society has won respect and has been able to exercise a beneficent influence. To complete this sketch of its career we may add that Mr. H. S. Munroe was the first president; he is succeeded by Mr. J. Parke Channing. No better men could have been selected as standard-bearers. The new officers include Mr. F. W. Bradley as first vice-president and Mr. C. W. Goodale as second vice-president. Here also the excellence of selection is obvious. Mr. J. R. Finlay was the secretary and Mr. W. R. Ingalls was and remains the treasurer. As far as relates to the personality of its officers, the society is peculiarly fortunate.

"And yet the Mining and Metallurgical Society of America is a fiasco. It masquerades under a name far too comprehensive. No group of 160 men has the right to speak for the thousands of mining engineers, metallurgists, and geologists contributing at this time to the industrial development of the American continent. If there be not 1000 competent mining engineers and metallurgists worthy to rank as properly qualified practitioners, then the mines and smelters of the United States, Canada and Mexico are worse served than we had supposed. At the very inception of the organization it was proposed to issue a Blue Book of the elect; it is true that this proposal was killed, but apparently the spirit that animated the proposal, however well intentioned, lived to stimulate an exclusiveness wholly uncongenial to the main body of professional men in America.

"The society has failed to be representative because it has aimed to be exclusive.

"Soon after it was started a number of men applied for membership, but most of them were blackballed. Among these were two or three men as fit as any of those already enrolled. Apparently a few egregious blockheads deemed that they could place themselves on a pedestal by limiting the membership to the select group who became charter members before a severe selective process has been set to work. The scandal created by the refusal to admit several first-rate men into the society led to a revision of the by-laws, whereby the election of new members was transferred from the society as a whole to the executive council. Since then the proportion of applications rejected has been sensibly diminished, but the society has not recovered from the irritation produced by the crude effort to be select by blackballing all applicants. Only 27 new members were added in 1909, and 8 members resigned, including two or three men of the highest repute.

"We note that the retiring president referred to the failure to enlist the many professional men that should be members of a society arrogating a national name. He said: 'We have every reason to be proud of the character and attainments of our present members, but we have not, as yet, enrolled even a majority of the reputable and desirable engineers of the country.' Speaking without prejudice, as one fortunate enough to be within the pale, the present writer deems it proper to lay stress on the wholly un-American sentiment that has led this new society into a great blunder.

"The attempt of a fortuitous aggregation of individuals to sit in judgment on the members of a profession that includes thousands of men of varying education and occupation has failed utterly. In the effort to remedy the nondescript character of the American Institute membership, the new society went to the opposite extreme.

"The result is to indicate the difficulty of applying any known process of selection.

"Thus, in justice to the Institute, and particularly its veteran secretary, it must be confessed that the generous policy is the better of the two, simply because, humanly speaking, no tribunal exists by which character may be weighed, abilities appraised, and accomplishment valued. Men who are fit to-day may be unfit a year hence; the man who blundered a few years ago may be among the most efficient now; the personal equation still remains an insoluble problem.

"A mining engineer is the man who does the work of the mining engineer; whether he does that work well or ill it is for a jury of his peers to decide; but who is to select the jury? No self-constituted tribunal can assume disciplinary powers. Among the charter members of the Mining and Metallurgical Society are several whom we, in the exercise of a most fallible judgment, would exclude; among those refused admission are several with whom we would be proud to be associated.

"The lesson is one that should be learned by all engineering societies; for example, by our (British) Institution of Mining and Metallurgy.

"It is well enough to require certain qualities and to promote homogeneity as nearly as possible, but it is easy to err on the side of hypercritical requirement. Engineering societies arrogating national and even international guidance of world-wide professional activities must be representative before they dare to be exclusive.

"A professional organization is not a social club. An institution with only 1200 fully qualified members or a society of 160 is not warranted in the assumption that the one represeuts all the mining engineers, metallurgists and economic geologists of the British Empire, any more than the other can be permitted to assume to be spokesman for the thousands of professional men engaged in honest and efficient work on the continent of North America."

The Electrical Testing Laboratories and Electrochemistry.

BY CLAYTON H. SHARP.

The electrical arrangements required for the conduct of any single electrochemical experiment are usually fairly simple and require from the laboratory in which they are conducted no elaborate equipment. There must be a supply of current of the proper strength and of the proper potential, arrangements for controlling and measuring the same, and the furnace or tank, or other vessel, containing the substance to which the electrical

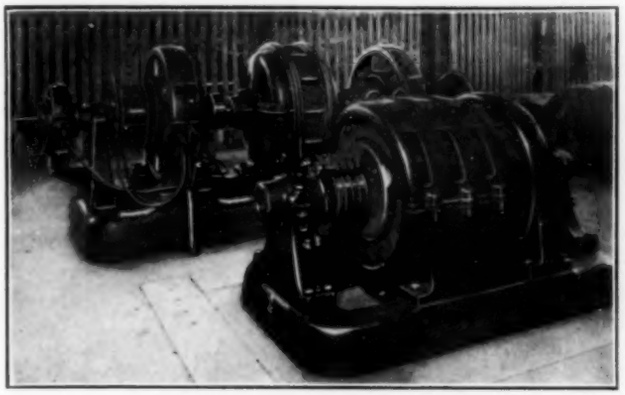


FIG. 1.—HARMONIC GENERATOR SET AND THREE-WIRE MOTOR GENERATOR.

energy is applied. When considering the laboratory equipment required for conducting electrochemical work in general, however, we are struck at once by the great range of the equipment and resources required to handle all classes of work. Taking the case of the supply of current alone, there must be available current of several thousand amperes at low voltage; current of several hundred amperes both direct and alternating at ordinary supply voltages, and current at very high tensions, but of limited intensity. From the one extreme of the heavy current of low voltage to the other of feeble current at high tension, it is necessary to be equipped to supply nearly any intermediate step.

Each step of an electrochemical process needs to be controlled by making accurate electrical measurements. This involves an equipment of electrical standards, and also a complete outfit of commercial electrical measuring instruments covering the entire range over which measurements may have to be made. The above requisites are the fundamental ones. When they are at hand and suitable space is also available, a laboratory may be said to be well equipped for carrying on electrochemical experiments of practically any kind, since in such research the energy-receiving device is usually of a special design, such as must be constructed by the experimenter in any case and cannot be provided for in advance. Laboratories in which facilities along the lines just outlined are available and in which the experimenter in electrochemistry may personally carry on such experiments as he desires, or may have them performed under his direction by the laboratory's testing force, are not so numerous as to make a description, in this place, of the equipment of such a one superfluous.

The main laboratory of the Electrical Testing Laboratories, being located in New York City, is within easy reach of a larger body probably of those interested in electrochemistry than would be the case if it were located at any other point in the United States. The plant is housed in a very substantial building, most of which is of fireproof construction, and which has a large stack, which formerly carried away the products of combustion of a battery of 14 steam boilers. This stack furnishes an excellent ventilating appliance. The points in the equipment of the laboratory which are of the most significance for electrochemical work will be described in much greater detail than those features which have no such immediate bearing, although they may be of great importance for other lines of electrical work. The description may fall under the general heads of the Supply of Current, the Standards and the Apparatus and Methods.

Supply of Current.

The supply of current is obtained from the New York Edison Company through underground cables. The main portion of the supply is furnished in the form of three-phase alternating current, 25 cycles and 6600 volts. The cables are capable of transmitting from the great Waterside Stations of the Edison company a large supply of energy in this form. Besides this, cable connection is had with the direct-current 120-240-volt service of the Edison company. Two cables furnishing this connection are taken from the street mains, while a third is connected directly to the end of one of the feeders of the three-wire system and consequently being a direct transmission from a substation equipped with rotary converters and storage battery furnishes current which is free from erratic fluctuations in voltage due to varied loads on the distributing mains. A total of 500 or 600 amp at 240 volts is available from this source.

In the ordinary operation of the laboratory the high-tension three-phase current is used for driving a 150-kw motor-generator which furnishes the requisite current for the life testing of incandescent lamps. The high-tension supply is also stepped down in a three-phase transformer, thus making available a supply of 25-cycle current at 220 volts. This may be used directly in experimental work and is useful also for driving motor-generators. The motor of the set for the life testing of incandescent lamps is wound for 6600 volts, while the generator is a three-phase, 60-cycle, 120-volt machine, from one phase of which the lift-test operations are carried on. The generator voltage is maintained very constant by a Tirrell regulator, supplemented by hand regulation through a sliding contact rheostat in series with the alternating-current helix in the regulator. Except at times of maximum life-test load a supply of 60-cycle current is available from this machine which is very useful in connection with electrochemical work.

The Edison direct-current service, besides being available directly for experimental work, is used to drive the elevator motor and other motors, to charge the storage batteries and to

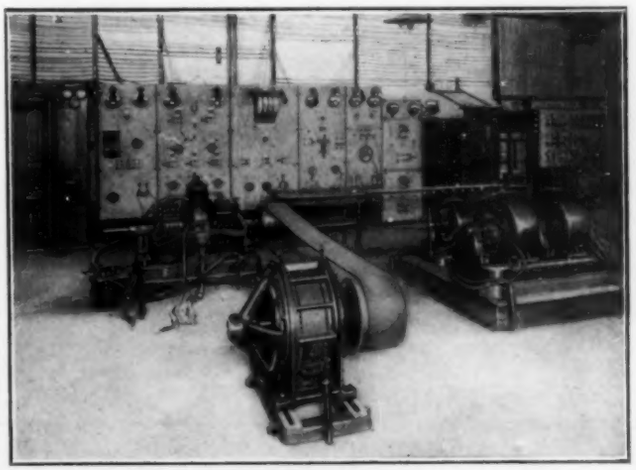


FIG. 2.—HEAVY-CURRENT DIRECT-CURRENT GENERATOR.

light the building. An additional three-wire service is furnished by a motor-generator of special construction, consisting of a 220-volt, 25-cycle induction motor of 50 hp rating, directly coupled to two direct-current generators, each rated at 120 volts and 15 kw. These machines are equipped with slip rings so that alternating current of approximately 37 cycles per second can be taken from them and so that their voltage can be controlled

by the use of Tirrell alternating-current regulators. In order to permit the use of this type of regulator each machine is equiped with a separate directly connected exciter. The very steady direct current at 120-240 volts furnished by this set is utilized chiefly for burning tantalum lamps on life test, it being a well-known fact that tantalum lamps have a somewhat uncertain life when operated on alternating-current circuits.

Two sources of direct current at low voltage are available. One of these is a set of four storage cells with an eight-hour discharge rating of 250 amp; these cells can be connected in series or parallel, as required, and are capable of delivering several thousand amperes for a short time. They are chiefly useful in connection with the calibration or standardization of instruments. Another source of very heavy currents is a double-commutator generator, which is belt-driven from an induction motor and the field of which is excited from a 120-volt circuit through a rheostat. Each side of the generator is rated to deliver 1500 amp at 8 volts. The sides may be put in series or parallel, so that 1500 amp at 16 volts are available, or 3000 amp at 8 volts. This is the normal rating of the machine. As high as 7000-amp currents have been taken from it without difficulty or distress, and the limit has not been reached. This machine is used at times for the calibration of large electrical

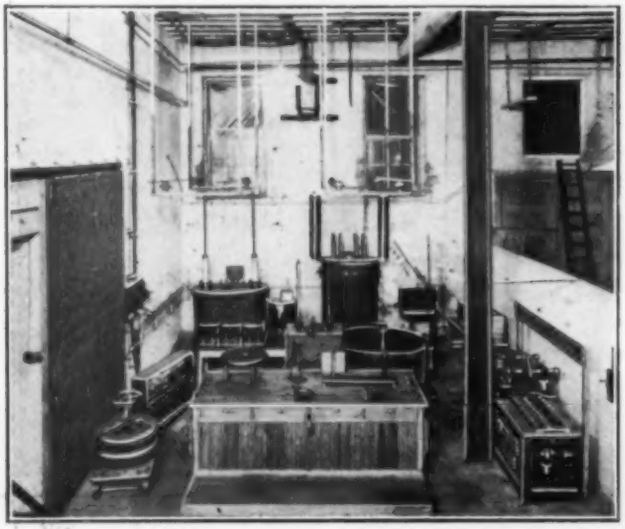


FIG. 3.—HIGH-TENSION LABORATORY. 250,000 VOLTS.

instruments or circuit-breakers, and when so used the terminals of the machine are short-circuited through the instrument and a standard manganin resistance. The current is controlled by varying the field current and consequently the voltage of the machine. Its utility in electrochemical work is manifest.

Heavy alternating currents are obtained by means of two step-down transformers, wound for 100 volts primary and 4 volts, 8 volts or 16 volts secondary. Each transformer is mounted on a truck so that it is readily portable, the truck carrying also a switchboard, by means of which the four sections of the secondary winding can be placed in series or in parallel. The normal rating of these transformers is 12 kw, so that they are capable of delivering continuously 3000 amp at 4 volts, 1500 amp at 8 volts or 750 amp at 16 volts. These two transformers can be operated in parallel or in series.

The equipment of storage batteries includes among others one battery of 70 cells with an eight-hour discharge rating of 60 amp; one battery of 70 cells with eight-hour discharge rating of 30 amp; four batteries of 10 cells each of 30 amp; one battery of 70 cells of 7.5 amp, and 400 cells of 0.75 amp. For the purposes requiring a greater range of potential than is available from the batteries, namely, about 1000 volts, a set of five direct-current generators is provided. These generators are driven by a common motor and each one is insulated from the earth and carries its own directly connected exciter. In series, these generators will supply direct current at 12,000 volts.

The supply of alternating current at high voltage is obtained from transformers. For voltages up to 6600 ordinary lighting transformers are used. For higher voltages there is available a transformer rated at 10 kw with 100-volt primary and four secondary terminals of 30,000 volts each, giving a total of

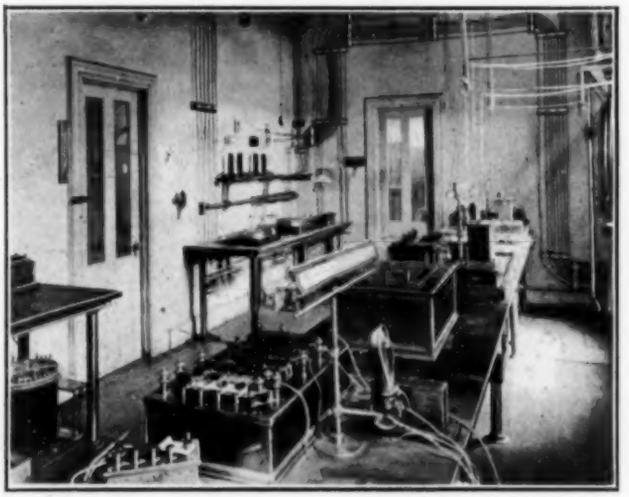


FIG. 4.—STANDARDIZING LABORATORY.

120,000 with the secondaries in series. There is also a transformer rated at 50 kw stepping from 220 volts to 250,000 volts. This last voltage seems high enough to meet all the present practical demands of testing and experimental work. The voltage of the secondary of the high-tension transformers is controlled by a variable-ratio auto-transformer in the primary circuit.

The main part of the work in which high tensions are required is involved in the inspections of high-tension insulators

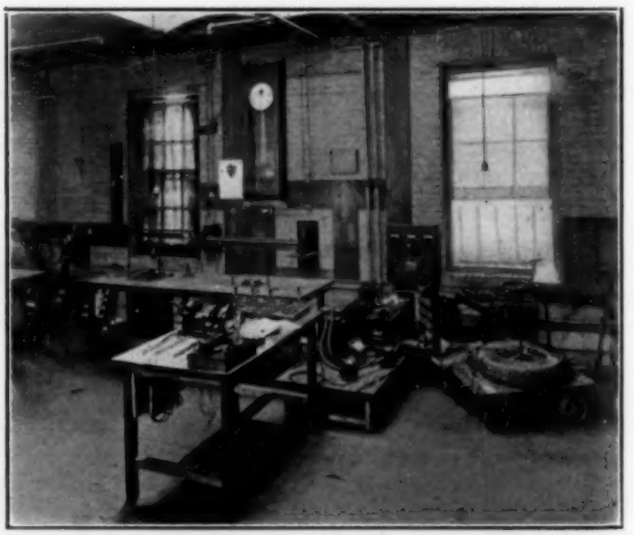


FIG. 5.—APPARATUS FOR STANDARDIZING CURRENT TRANSFORMERS (UP TO 5000 AMP).

for long-distance transmission lines. These inspections are made in the insulator factories.

There are two other sources of alternating supply which are, however, chiefly interesting in connection with testing and standardizing work. One of these is a pair of alternators exactly alike, placed on the same bedplate. These machines may be coupled together or may be driven separately at any required

speed, three-step pulleys being employed for the wide variations in speed and motor control for the finer adjustments. They are of the revolving-field type with their armatures arranged so that they can be rotated by means of a worm through 180 electrical degrees. The particular value of this arrangement is in connection with tests of meters where power-factors, other than unity, are desired. For this purpose the current for the field coils of the meter is taken from one of the generators, usually with a step-down transformer, while the potential is taken from the other generator and any desired phase relation is obtained between the current and voltage by shifting the armatures.

The other set referred to consists of a direct-current motor having three alternators on the same shaft. The motor is wound for 120-240 volts to give a wide range of speed variation. The alternators have the numbers of their poles in the ratios of 1:3:5. Their armatures are wound to carry the same current. The armatures of the two generators having the largest number of poles can be rotated by means of a worm. This set is designed primarily to furnish alternating current of any required wave-form by the superposition on the fundamental of the third and fifth harmonics. The amplitude of these harmonics is controlled by the field rheostats, while their phase relations can be changed by moving their armatures. Apart from its usefulness for the purpose for which it is directly designed, this set, furnishing as it does the wide range of alternating frequencies up to 300 cycles per second, is a very practical one in connection with the testing work.

Standards.

With the introduction of new and simplified methods of measurement, the discovery of new materials, the adoption of new designs, and the establishment of the great national standardizing laboratories to which the question of the accuracy of standards can be referred, the making of electrical measurements of precision has been in recent years greatly simplified.

The fundamental standards which must be on hand for electrical work are those of electromotive force and resistance. It is desirable also to have suitable standards of capacity and of inductance. The universally accepted standards of electromotive force are the Clark cell and the Weston cadmium cell. Both of these types of cell are at hand. The advantage of

FIG. 6.—CHEMICAL LABORATORY.

having both types is that the accuracy of the standards can be determined with somewhat greater certainty if it is possible to check the two types against each other. The ratio of the electromotive force of the Weston normal cell to that of the Clark cell is known with very great accuracy and hence an intercheck of this kind is of considerable value. For practical work, the Clark cell is very little used. The Weston normal cell, i.e., the cadmium cell, with an excess of cadmium sulphate, forms the most desirable primary standard. It is found in the operation of the laboratory, however, that it is usually more convenient to use secondary standard cells having a zero temperature coefficient. Consequently, the cells manufactured by the Weston Electrical Instrument Company (in which the solution of cadmium sulphate is saturated at 4° C.) are in con-

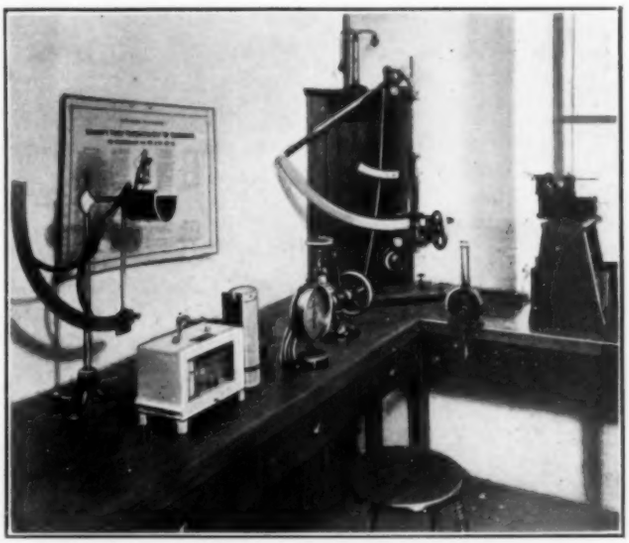


FIG. 7.—SCHOPPER TESTING MACHINE AND IVES' CALORIMETER IN PAPER LABORATORY.

siderable use. Cells of Hulett's reversible type, containing 1 per cent of sulphuric acid, are also in use and are very convenient working standards. These cells have the advantage that they are not damaged as a result of allowing them to deliver very considerable currents. Considerable success has been had also in the use of large reversible cadmium cells as working batteries for high resistance potentiometers. Two such cells of the dimensions given by Professor Hulett will deliver the current required by a 15,000-ohm potentiometer with remarkable constancy. The current may be interrupted when the potentiometer is not in use, and on closing the circuit little or no adjustment of the auxiliary resistance is necessary unless measurements of a considerable degree of refinement are to be made.

Standards of resistance of the Reichsanstalt type, having manganin as a resistance material, ranging in resistance from 100,000 ohms to 0.0001 ohm by steps of 1/10, are at hand in duplicate and triplicate, while oil-immersed standards of the Bureau of Standards type, ranging from 1 ohm to 100,000 ohms, are also used. While variations in some of these standards have at times been detected, yet they are in general so constant that they make the measurement of resistance exceedingly easy. In the measurement of current strength, the modern practice of using the method of the fall of potential through a manganin resistance is adopted, although a silver voltameter is also at hand. For purposes of measurement of this kind manganin resistances designed to have a maximum capability of dissipating heat are used. The largest of these is a resistance of 0.0001 ohm through which a current of 5000 amp can be passed continuously, and a still larger current for a short interval of time.

A standardized mica condenser serves as a standard of capacity while fixed and variable standards of inductance are also at hand.

For the measurement of temperature, there is available a set of four standard thermometers by Richter, in Berlin, covering the interval between zero and 400°, with 0.5° graduations and with the zero point and 100° point on each thermometer. For temperatures above this, a Callender platinum thermometer

is available. Special thermometers are used for calorimetric work.

In the department of photometry, the equipment of standards includes two Hefner lamps and two 10-cp pentane lamps, one of which is of American and the other of English manufacture. These lamps, however, are not referred to as standards in the ordinary course of photometric work. The real standards are constituted by a series of incandescent lamps carefully seasoned and compared. The value of the unit of luminous intensity represented by these standards is the candle as recognized by the Bureau of Standards in Washington, by the National Physical Laboratory of England and by the Laboratorie Central d'Électricité in France. The greatest care is taken to avoid the possibility of any variation from the photometric standards once set, copies being continually made and compared with the older representatives of the standard and a frequent reference being made to the Bureau of Standards.

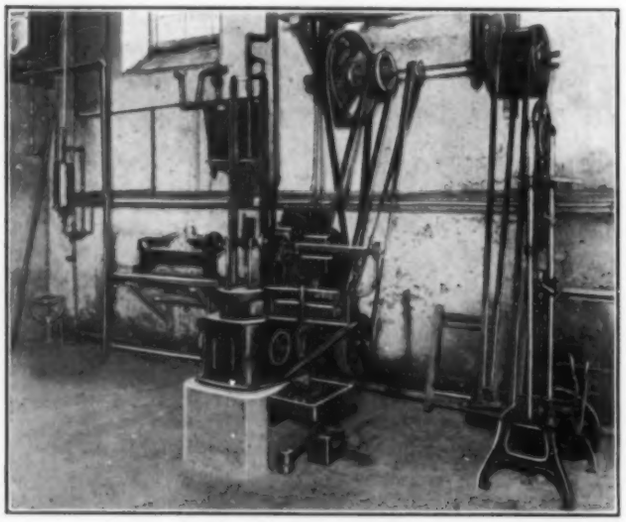


FIG. 8.—TESTING MACHINES.

Incidentally to the above statement of the fundamental electrical and other standards used, the fact may be mentioned that the laboratories are entrusted with the periodic checking and certification of the accuracy of the standards of measurement of a number of the largest electricity supply companies in the country.

Apparatus and Methods.

In the measurements of electromotive force, the calibration of voltmeters, etc., the potentiometer and the standard cell are employed. Potentiometers both of the high-resistance and of the low-resistance type are used. For operations in which it is desirable to move the potentiometer from place to place the low-resistance type has the advantage that a sensitive pivoted galvanometer which is quite portable and which requires no leveling can be used with it. For precise measurements, the high-resistance potentiometer with a reflecting galvanometer is usually employed. Voltages higher than 1.5 are measured by the use of the volt-box multiplier. For the high-resistance potentiometer, the volt-boxes are of 100,000 to 200,000 ohms total resistance; for the low-resistance potentiometer, from 5000 to 10,000 ohms, thereby insuring sufficient sensitiveness in working with the portable galvanometer.

For the measurement of alternating voltages, instruments of the soft-iron type, of the electrodynamometer type and of the electrostatic type are at hand. Of the latter type, mention may be made of a Ayrton-Mather reflecting instrument giving full-scale deflection with 7 volts to 8 volts; a Kelvin multicellular electrostatic instrument specially equipped with a telescope and scale and reading to 150 volts, and a Westinghouse instrument reading directly to 120,000 volts, or operating in two lower ranges when one or both of two oil-insulated condensers are short-circuited. The last-named instrument has its moving parts entirely immersed in oil, and indicates high tensions in a very satisfactory way.

Evidently not all of these instruments can be standardized on direct current. The soft-iron instruments and also the electrodynamometers when used on currents of high frequency are subject to error. These are checked by the use of electrostatic instruments as transfer instruments from direct to alternating voltage. The Kelvin multicellular voltmeter with telescope and scale referred to above is the most important instrument for this purpose and when carefully used yields results of relatively high precision.

Ordinary resistance measurements are made on a decade type Wheatstone bridge. For precise work the bridge is used whenever possible by the substitution method. For instance, if another decade box is under investigation, and the 10 coils of 100 ohms each are being measured, the 100-ohm reference standard resistance is first measured by the bridge and then the 100-ohm coils in the box. By this method errors of the bridge are eliminated.

The measurement of low resistances is usually carried out by means of the Kelvin double bridge, though the fall of potential method with a potentiometer and standard resistance is sometimes employed. The Kelvin double bridge used is of the dial pattern with four decades. Among its uses is the measurement of the conductivity of copper and other materials. To assist in the measurement of the conductivity of copper, a set of copper standards of resistance have been prepared, one for each two sizes of the Brown & Sharp wire gage. These consist simply of pieces of copper wire, to the ends of which lugs for convenient attachment are securely sweated, and to which at a distance of about 1 m from each other potential terminals are permanently attached. The resistance of each of these standards is carefully measured at 20° C. by comparison with a manganin standard, the copper being immersed in an oil bath. Knowing the resistance of the standard, a table is prepared to show what length of copper wire of a given weight per unit length would have the same resistance as the standard, if its conductivity were 100 per cent in terms of Matthiessen's standard. The wire, the conductivity of which is to be determined, is cut to a length of exactly 120 cm, and is weighed. It is placed in series with the copper standard and knife edges are pressed upon it, giving potential connections at the distance apart which is indicated by the table. The bridge then reads percentage conductivity directly.

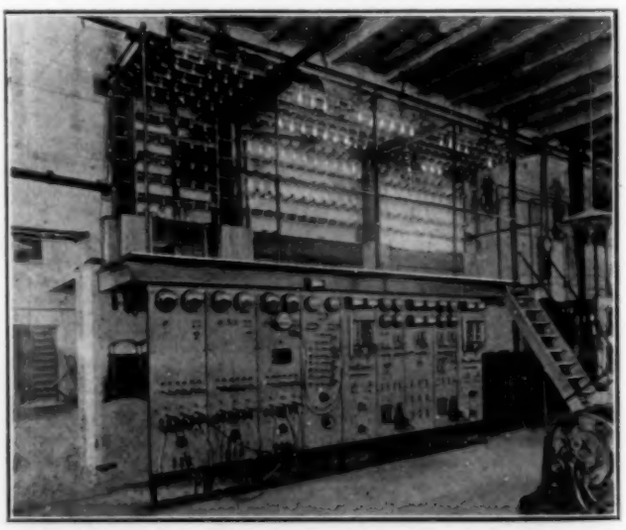


FIG. 9.—SWITCHBOARD AND TANTALUM LAMP LIFE TEST.

In the measurement of high resistances, such as that of insulating materials, in wire and cable tests, etc., a sensitive high-resistance d'Arsonval galvanometer is employed. The source of electromotive force is a special battery of 150 small accumulators installed on large rubber insulators in such a way as to insure immunity from grounds. Where the sensitive galvanometer method of measuring resistance is inadequate, the loss of charge method, using a Kelvin electrostatic voltmeter equipped with mirror, telescope and scale, to measure the potential, is employed.

An abundant supply of ammeters is on hand which can be calibrated accurately, using the standard resistances of low denomination and high-current carrying capacity which are constructed for the purpose.

A set of Kelvin balances, the largest of which will carry 1000 amp, is of particular use in connection wit hthe standardization of alternating-current ammeters and of series transformers for the measurement of current.

Use is made also of a bank of incandescent lamps as a means of standardizing small alternating-current ammeters. The voltage on the lamp-bank is measured by an alternating voltmeter of the electrodynamometer type which gives the same indications on both direct and alternating voltages. The lamp-bank is standardized on direct current and is brought to the same voltage on alternating current, whereby the value of the current is determined.

A supply of wattmeters is also on hand, including precision wattmeters of the Duddell-Mather and of the Westinghouse types. These can be standardized on direct current. Convenient apparatus is set up for the standardization of voltmeters, ammeters and wattmeters, including integrating wattmeters.

The important question of the precise determination of the ratio of transformation and of the phase displacement of current and potential transformers used in the measurement of large currents or high voltages has been gone into very thoroughly and a method developed and apparatus constructed for accomplishing the same. By this method the ratio of transformation is given as the ratio of two resistances and the phase angle is computed from the indication of an adjustable mutual inductance. The design and construction of nearly non-inductive manganin shunts of large current-carrying capacity has been involved and this has been successfully carried out in the laboratory work shop. The largest of these carries 5000 amp with water cooling and has a resistance of 0.0002 ohm. The phase angle between the current and the potential difference in this shunt has been measured and found to be 18 minutes.

By the use of transformers standardized as above the range of precision measurements in the laboratory is extended almost indefinitely.

A supply of apparatus, including among other things a Koepsel permeameter and a Picou permeameter, is on hand for the determination of the magnetic properties of iron and steel. The well-established ring method of testing iron with a ballistic d'Arsonval galvanometer, standardized by means of a mutual induction coil, is preferred for work of this character.

An oscillograph and a "point-by-point" apparatus for getting alternating wave forms are also set up and available for use.

A bomb calorimeter is used for determining the calorific values of coal, and a Junker's calorimeter for determining that of gas.

A small but well-equipped chemical laboratory is provided in which all of the ordinary analyses and other chemical operations required can be carried out. This is furnished with a hood and with gas, hot and cold water and compressed air. Opening from the chemical laboratory is a small balance room in which the balances are supported on a firm shelf.

A spectrophotometer of the best construction, and also an Ives' colorimeter, are available for use in such chemical and other tests as require a careful analysis of color.

The apparatus is also on hand for the accurate comparison of working thermometers with standards. This apparatus has been developed chiefly for the purpose of checking clinical thermometers along the lines pursued by the Bureau of Standards.

A series of machines by Schopper, Riehle and Olsen are on hand for testing the tensile strength of materials up to a maximum of 15,000 lb. This series will soon be supplemented by a machine for tensile and compression tests up to 200,000 lb., and also by one for torsional tests up to 240,000 inch-pounds.

A well-equipped photographic darkroom is also provided.

The laboratory for the measurement and testing of various sources of light is most complete. Its equipment includes a Matthews' arc photometer installed in a photometer room 70 ft. long and used for determining the mean spherical candle-power, the mean hemispherical candle-power and the distribution of light in a vertical plane, of arc lamps and of large gas lamps, such as are used in street lighting, etc. For the determination of mean spherical and mean hemispherical candle-power of large sources of light, there is also an integrating sphere 2 m in diameter constructed of sheet iron and conveniently arranged to give access to the interior and to fit it for practical use.

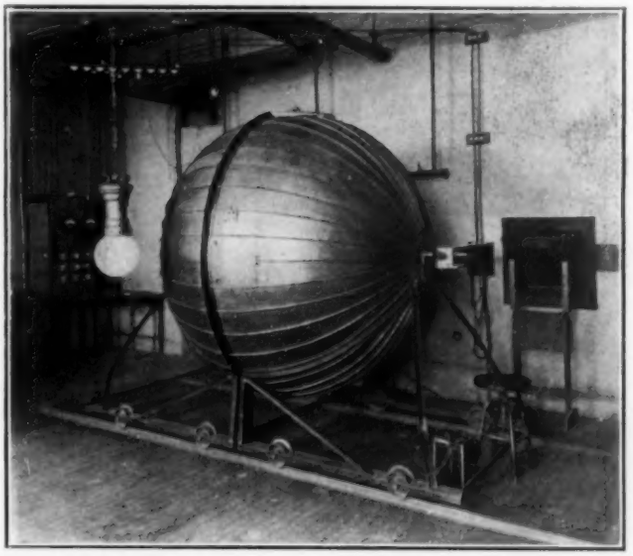


FIG. 10.—INTEGRATING PHOTOMETRIC SPHERE.

A photometer room is set aside chiefly for the photometry of gas lamps. This is equipped with the necessary gasometers, meters, pressure regulators, etc. The photometer track in this room is 5 m long. There is an arrangement of three very large mirrors placed on a frame which can be turned to any angle about a horizontal axis, by means of which the intensity of the light emitted at any vertical angle from a lamp is thrown on to the photometer disk. By the use of this apparatus the curve of vertical distribution of the intensity can be obtained without disturbing the lamp.

The standard photometer room is equipped with a long photometer bar of the Reichsanstalt pattern carrying a Lummer-Brodhun contrast photometer. The normal distance between lights in this photometric outfit is 5 m. The arrangements, however, are such that this can be varied at will. The electrical measurements are made by means of a potentiometer and standard cell. On this photometer, as on all of the others, the greatest attention is given to the question of screening the photometer disk from the influence of stray light, an important point which is too often overlooked in photometric work. The work of this room consists largely in the standardization of incandescent lamps as standards of luminous intensity. The lamps to be used for this purpose are carefully seasoned until

they reach the point at which the rate of change in candle-power is very slow. In the process of standardization their candle-power is read carefully by different observers on different days. In some cases the process of standardizing a lamp extends over some months. In this work, as in all the photometric work, the substitution method is followed, a set of standard lamps first being controlled against a comparison lamp, and afterwards the lamps to be standardized, which are then placed in the same receptacle and are measured by the

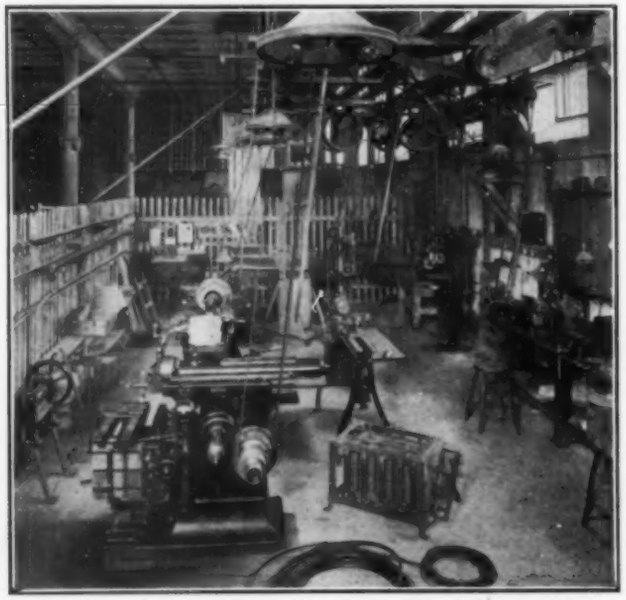


FIG. 11.—MACHINE SHOP.

same instruments as have been used in the case of the standard lamps. Several hundred such lamps are prepared and sold each year to lamp makers, users and photometrists generally.

A large part of the photometric work is incidental to very elaborate inspections and tests of incandescent lamps, which the laboratories are carrying on, and which cover many million lamps per year. The chief part of the inspectional work is carried on in the factories in which the lamps are made, but samples of the lamps so inspected are brought to the laboratories for purposes of a life test. These sample lamps are carefully read on industrial photometers and are put on racks to burn at their proper voltage to the nearest tenth of a volt. At approximately 100-hour intervals, they are removed and re-photometered, whereby their life history is determined. Some 3000 lamps can be life-tested simultaneously.

The industrial photometers, by the aid of which this work is performed, are a modified form of the photometers which are in use in lamp factories. They have been very greatly refined in details, so that they are capable of yielding results of relatively great precision. The Leeson star disk form of photometer is used in this class of work on account of its simplicity and on account of the convenience with which the operators can observe it.

In connection with the incandescent lamp work, there is a Matthews' integrating photometer for determining the mean spherical candle-power of incandescent lamps, and also an integrating sphere 30 in. in diameter which has been found to be a superior instrument for this purpose.

There are also various portable photometers which are found to be of the greatest value in the measurement of distribution of light from sources of large dimensions, in the measurement of mean spherical candle-power in connection with the spheres, and particularly in the measurement of the illumination in rooms, and of the candle-power of lamps on the street. A most convenient form of photometer for this purpose has been developed as the result of the experience so gained.

This laboratory is not without that most important feature of any large working laboratory, namely, a machine shop. Various machine tools of the best types are therein installed and are used for the repair of apparatus and for the construction of new apparatus as required.

A feature of the laboratory consists in a number of private rooms which can be rented by those wishing to conduct their own experiments. These rooms are supplied with water, gas, compressed air, etc., and with electrical connections to the main laboratory switchboard, whereby all electrical currents, both direct and alternating, can be obtained.

The uses to which these private rooms have been put are most varied, but more of the work which has been done has been of an electrochemical character than of any other. Among the work which has been done, bearing upon electrochemical research, has been the experimental development of new types of electric furnace, and by two different parties, on the fixation of atmospheric nitrogen. In the case of one of the latter the plant installed was of such a size as to give data on the industrial value of the process, involving the question of cost, etc. Experiments have also been made in the fusion of quartz for the production of silica vessels, and in the use of the electric furnace in annealing transformer plates. Many tests of primary and secondary batteries have been made. Experiments have been carried on looking to the development of new insulating materials, etc.

The equipment, of which the above is but a meagre description, is being added to continually as requirements indicate, the purpose being to maintain the laboratory in a high state of efficiency and to keep it abreast of all of the latest developments along its line of work.

Plans have been prepared for apparatus which will make a considerably larger supply of alternating current available for general laboratory work, and particularly for electrochemical work. This apparatus will consist of a step-down transformer in connection with an autotransformer whereby any required voltage can be obtained between 5 volts and 600 volts by steps of 5 volts. Its normal rating will be of 150 kva. The considerable supply of power furnished through this apparatus

FIG. 12.—INTERIOR OF PRIVATE LABORATORY.

will enable electrochemical experiments to be carried out on a fairly good scale.

It is hoped and believed that the Electrical Testing Laboratories will be an important factor in the future development of electrical science along the chemical lines as well as along the electrical engineering lines to which its attention has in the past been chiefly devoted, and in which it has received extended recognition and substantial encouragement from manufacturers, users, engineers, experimentalists and many others.

Causes of Non-Uniformity of Blast Furnace Operation.

BY EDWARD B. COOK.

The writer has felt for some time that there is not enough co-operation between scientific men engaged along mechanical and metallurgical lines and the operating men who are running the blast furnaces. The cause of this is misunderstanding. The practical man feels that the scientific man does not understand practical conditions, and that although many of the suggestions made are of value they are impracticable.

It is the object of this article to take up the items, one by one, given in Prof. J. W. Richards' article on blast-furnace operation, printed in this journal, January, 1910 (page 18), and also to discuss the chief difficulty in blast-furnace practice which is causing a great deal of trouble and loss of money. No new information is contained. It is simply a statement of the practical man's troubles and his point of view.

Composition of Ore, Flux and Fuel.

There can be no doubt that this is a matter of great importance and to-day it is usually well looked after. Even where numerous ores, frequently irregular, are used in a furnace, the manager insists on knowing what the ores are and is able to mix them in such a way that there is seldom much disturbance of the flux. At many places cokes varying greatly in ash and sulphur are used, and a fairly uniform iron made from them. There is more or less leeway in flux in a good-working furnace, i.e., the slag can vary 3 per cent or 4 per cent in acids without throwing off the iron, provided the condition does not continue too long.

It has been found helpful at some plants to have the blast-furnace chemist make a monthly report of his analysis of all the materials entering into the furnace throughout the month and make up a theoretical analysis of pig iron and slag, and compare these with the actual analyses from the furnace. This makes the laboratory an integral part of the furnace operation, and if the chemist's reports do not check closely with those of the furnace, he is under the necessity of making some explanation, and he cannot blame it on the sampler, as the sampler is under his direct charge.

It is found that the theoretical slag is usually 2 per cent lower in acids, i.e., silica and alumina, than the actual slag.

Size of Lump.

It is impracticable to keep all the material entering the furnace, using 2000 tons of raw material a day, free from rain and snow—that is, irregularities on account of weather conditions. It probably will always be impracticable, particularly with such a bulky material as coke.

This, however, is not as troublesome a condition as might be expected. Within the last year it has only proved of annoyance once at our plant, and then was a disturbing factor for three days. Water, of course, is of benefit, and is being added largely to the charges before entering the furnace, usually after the material is weighed.

The Western furnaces during the past year have used large quantities of water—in fact, equal to from 5 per cent to 10 per cent in weight of all the ore put into the furnace. The purpose of this is to keep the top of the furnace cool, and also to prevent the loss of fine ore. In some places this water is measured by meter, but oftener it is put in at random and varies greatly in amount. There is no objection, usually, to the water going into the furnace. The only objection is to the varying quantities of water in the raw material before it is weighed, and the consequent changing of the burden and flux of the furnace.

As a general proposition, it is advisable to have all the material going into the furnace broken to a uniform small size. It is, however, impracticable to break all of this material down by sledges, and there are many objections to breaking it with crushers. For instance, at a German plant I inquired of a director whether they did not break any of the material. He replied that 12 years ago they did, but it had been discontinued at that time in order to save flue dirt, and that occasionally they break down large ore with sledges, but most of the material went into the furnace in good-sized lump. Even the dense Swedish ores are charged in big lumps. In this country there have been several instances where furnaces would not work on small limestone, and it was found necessary to use large stone in order to prevent top slips.

On a furnace that is working well, material irregular in size can be used without seeming detriment. As a general proposition it is well to have stone broken down to 4-in. size, provided it can be screened afterward and the dust taken out. It is well to have hard magnetic ores, and hard ores of all kinds, crushed down small, provided the percentage of dust so formed is not excessive, for in many ores loss through dust on account of crushing will very quickly use up the saving to be gained in improved furnace work by better preparation of the ore.

In regard to size of coke, in the same day I have had one successful blast-furnace manager tell me he attributed his success to the use of small coke, and another man equally successful say that he attributed his success to the use of large-size coke.

One cause of great trouble in a blast furnace is the practical man's lack of knowledge of the fusible slag. It is remarkable how little is known about the presence of spinel in blast-furnace slags, and many furnace managers are in difficulty to-day on this account. Others are using a slag entirely too infusible, unable to contain much sulphur, and are making a good deal of bad iron in consequence. The justification for this lack of knowledge is that few of the blast-furnace men have had the advantages of scientific training, and even those that had, do not know where to go for detailed information in regard to slags.

Intervals of Charge.

There can be no doubt about the necessity of regular charging. We are, however, very much troubled with poor distribution, and although great advances have been made in the last six years, so that now there can be no doubt but that mechanically filled furnaces with revolving tops give as good distribution as the old hand-filled furnaces, still we feel that the distribution is not all that it should be.

The modern furnace is charged as continuously as possible to be consistent with good distribution, i.e., in order to get the best distribution, a certain number of pounds of coke or a certain number of pounds of ore, or both, must be lowered in the furnace at one time in order to give a proper thickness or layer on top of the furnace. Most furnaces are equipped with a recording instrument showing the gas pressure on the furnace top. It shows exactly when the furnace was filled, day and night, and is a great aid to the superintendent in obtaining regular charging. We will probably never attain absolutely continuously filled furnaces until we have some sort of revolving or stirring arrangement to give distribution, such as has been adopted in modern gas producers.

Running Out of Iron and Slag.

The writer has frequently heard of the continuous-running cinder notch, but has never seen one, either in this country or abroad, and certainly would not venture to put any in at a blast furnace which he was running. The reason for this attitude is that furnaces appear to accumulate in the hearth a certain amount of so-called "dirt," which is mostly fine coke—not consumed in the furnace—together with some graphite. The only way to get this material out of the furnace is to wash it out with the slag.

If a small cinder notch is used it is impossible to keep the furnace clean. If too large a cinder notch is used the furnace is kept clean by washing out this material, but there is a much larger loss of iron carried out of the furnace mechanically with the cinder.

The manager tries to compromise between these conditions and often changes the size of a monkey or cinder notch, according to the condition of the furnace. It is hardly likely that this mechanical difficulty of the ordinary blast furnace will ever be done away with.

In regard to tapping of iron, most large furnaces to-day are tapped every four hours, some of them every three hours. They are tapped at a regular time in this country.

There is one furnace in England, however, which is used as a mixer for the steel works, in that it is tapped for a ladle of iron whenever the steel works asks for it. This is a small furnace, and the condition could not be met with our present skill on big furnaces. It is essential that a body of iron of certain size be accumulated in the blast furnace or else the bottom builds up so that the furnace cannot be tapped. There is no slacking of the wind to flush, nor is there any slacking at cast, ordinarily, except to shut in the iron notch. This time of "shutting in" has been reduced to an average of 30 to 40 seconds. We have run one furnace for two weeks without even slacking the wind to shut in the furnace. We find, however, that there is danger of burning men in this practice and that there is very little detriment to the furnace by throwing off the wind for 30 seconds once in four hours.

Temperature of Blast.

Although equalizing stoves have been invented for a number of years, to the writer's knowledge they are only in use at two furnaces in the United States. The ordinary blast-furnace manager is not prepared to recommend the expenditure of the money required for this installation, and practically no owners are willing to make the expenditure, even when the blast-furnace manager does recommend it.

Most managers attempt to keep the temperature of the blast fairly regular by regulating a cold-air mixing valve. This, however, has many objections, as frequently the air does not mix properly, and one side of the furnace is receiving much colder air than the other. Another idea is to work two stoves continuously on the furnace—and have only two stoves on gas—regulating the cold-blast valves of the two stoves on the furnace so as to maintain the temperature reasonably uniform.

The difficulty with all these devices is that the temperature cannot be maintained uniformly high, but is usually maintained uniformly low, and there is a great loss of heat units.

There is not nearly as much irregularity caused in a blast furnace by a variation of heats of 200° in one hour as would be supposed.

Furnaces run along for years and have their heats vary from 100° to 200° every hour without showing unusual irregularity as compared with those receiving regular heats.

In this country we have been unable to use high heats. The stove equipment is far below that of German practice, but most managers do not use what they have—whether on account of our coke and ores or lack of knowledge of blast-furnace construction, we have been unable to get our furnaces to do good work on heats as high as those used in Germany. Up to two years ago the successful manager was usually using not over 900° Fahr. To-day 1000° to 1100° is being used by many managers, but there are still a large percentage sticking to the low heats.

When in Germany I asked a blast-furnace director why he did not run his heats over 1475° Fahr. He replied that the furnace would not stand any higher heats, but stuck fast, and, indeed, it was necessary for him to use all cold air after each cast for half an hour to get the furnace to "move off," i.e., start to settle again.

In the East with magnetic ores higher heats are used, but even there there seems to be a limit of about 1200° except at certain times when the furnace turns cold. It will be a very great advantage to the blast-furnace business if someone can devise a furnace on which high heats can be used continuously.

Moisture of the Blast.

There can be no doubt but that the low moisture of the dry blast is the great value and that perfect uniformity is a second consideration. One blast-furnace manager regularly used steam in his air in irregular weather in order to keep the moisture entering the furnace uniform and to keep the furnace from sticking fast by getting too hot high up on low-moisture days. This, however, was unsatisfactory.

It is evident to the manager that irregular moisture, around 1 gr., is of very little importance, while moisture around 2 gr. makes a great deal of difference, so that although uniformity is of value, the main thing is *low* moisture.

In regard to keeping exactly the same weight of oxygen entering the furnace, this also is a refinement which at present we have not found any great necessity for. I know of several managers who varied the revolutions of their blowing engines in proportion to the temperature of the air, so as to deliver as nearly as possible the exact same weight of oxygen to the tuyeres, but this has always been discontinued after a certain length of time, and I do not know of anyone who is attempting to do it to-day. Blowing engines are carefully watched, however, and revolution counters used to make sure that the same number of revolutions are run hourly, also clock-speed recorders to show that the revolutions have been regular during the hour.

At our dry-blast furnace we have attempted to keep the temperature of the air entering the blowing engines regular as well as to keep the moisture regular. We have not, so far, been able to demonstrate that this regulation of the temperature is essential.

The writer does not wish to take the position that regularity as regards composition of material, size of lump, interval of charging, running out of iron and slag, temperature, moisture, and weight of blast are unnecessary and not worth the trouble of attempting, but the point to be made is that practically none of these things, as ordinarily cared for in an average plant, are interfering with fairly regular running and reasonable profits. There is, however, one particular feature which does materially and seriously interfere and which will now be considered.

Furnace Lines and Accumulations on the Bosh.

There is a saying among blast-furnace men that if a furnace is built right anybody can run her; if she is not built right nobody can—and the truth of the matter is that none of us know how to build one right.

There are certain things that have been developed—for instance, that it is not economical to attempt to burn over 4 lb. of coke per square foot of hearth area per minute, and that the furnace must be built of certain size of hearth in order to make the requisite tonnage.

From experience it has been found that it is not well to have too great velocity through the tuyeres—in fact, a velocity measured by a difference in pressure of 1 lb. is about right. It has also been determined that the economical height is somewhere between 85 ft. and 95 ft., but it is not known what is the proper height of the bosh or the proper angle, nor consequently the diameter of the bosh.

It is not necessary here to go into the lines in detail, nor devices for maintaining the lines at stock line, hearth, etc., except to say that there has been great improvement in recent years.

Accumulations on the Bosh.

In *Stahl und Eisen* Professor Osann speaks in his article on the dry blast of furnaces that do not run regularly, the usual cause being that the sectional area of the furnace has become lessened. This is exactly the trouble, and is the trouble which keeps the blast-furnace manager awake at nights and is responsible for his general uneasiness. This lessening of area is no longer due to the old high-melted scaffold, which troubled our fathers. On account of improved working conditions and

lower fuel consumption the high melted scaffold has practically disappeared and we seldom hear the word "scaffold" to-day.

The present lessening of area is about at the top of the bosh, sometimes just below the top of the bosh, and sometimes just above. A furnace in this condition is usually spoken of as having accumulations on the bosh or being a dirty furnace. Sometimes this condition happens in blowing-in, and the furnace is never able to do good work. At other times it will hardly be felt for the first year. Ordinarily, however, it occurs in from four to six months. It has been noticed again and again that a furnace will do very good work for four to six months and then will start to drop back in tonnage, and the fuel consumption will increase largely on account of the irregular settling, i.e., hanging and jumping.

The cause of this accumulation is not known. To be sure, bad lines or any mistake in running or charging seems to accentuate it. There is also a difference according to the material used in the furnace. For instance, there is a great deal more trouble of this kind with magnetic ores than there is with hematites. The material seems to be largely unreduced ore with more or less lime. Some managers blame it on their limestone, others on the quality of the ore used, and still others blame faulty distribution. These are the main causes advanced for furnaces where everything else is closely looked after. Of course, excessive velocity of wind through the tuyeres or some other mistake of this kind accentuates the trouble.

The trouble is world-wide, but is very much worse in some districts than in others. If this condition cannot be remedied, the furnace has to go out of blast or run on very irregular iron produced at excessive cost. If hematite ores are being used, it is not so difficult to clean the furnace, but with magnetic ores the trouble is frequently fatal, as the material, if by chance it comes off at once, is sure to bung up the hearth of the furnace. The cleaning process in any instance takes time and is a very expensive matter.

In the way of prevention, changing the lines of the bosh has been tried without much resulting benefit. Bosh jackets have been substituted for bosh plates, and *vice versa*—in fact, the blast-furnace managers keep wandering around in a circle as far as these things are concerned, always wanting what they have not got. There seems to be no way whatever to absolutely prevent the trouble. In England it is met at one plant by tuyeres on the bosh, which are used either part of the time or all the time. This, however, must greatly interfere with the zone of fusion in the furnace and cause high fuel consumption.

The men who are making the least "off" iron and having the least trouble to-day are those who are blowing slowly, keeping stove heats in reserve, and giving the furnace cleaning blanks every three or four days to prevent the formation of accumulations on the bosh.

Professor Osann suggests that the dry blast be used, together with controlling amounts of steam. Steam or water put into the tuyeres undoubtedly help to remove the accumulation, but dry blast will not do it.

As a preventative, dry blast is a great help, as it lowers the zone of fusion in the furnace and brings whatever accumulations there may be lower down. As a proof of dry blast's help in preventing this trouble, it is noticed that the dry-blast furnaces last year surpassed all other furnaces in average work. It is the writer's opinion that the same furnaces using the same material will take twice as long before being inconvenienced by accumulations on the bosh if dry blast is used, but dry blast alone will not remove the accumulations once formed.

While the furnace is "building"—that is, accumulating on the bosh—the work is excellent as the radiation from the bosh is reduced, the heat concentrated in the center of the furnace, and conditions are ideal. When the "building" has continued too long, however, irregular settling interferes with any kind of proper work in the furnace. If the bosh is kept clean by the use of short large tuyeres good work is impossible. The practice in Germany, and in some places here, is to try to adjust these conditions with the tuyeres, but results are not altogether satisfactory, and there is a certain period of high cost while the furnace is being cleaned.

The salvation of blast-furnace practice is going to be a furnace which can be blown out and put in again in a short time and without excessive expense. Mr. James Scott has done more than any other man in the United States along this line, as he has had the courage to put up a blast furnace containing only 12-in. of brick on the inwall. It can probably be put out and in again within two weeks and without great expense.

So far this furnace has worked very well, and is proving of particular interest, as it gives new information in regard to the loss by radiation and also in regard to the temperature of various zones in the stack. If this type of furnace is generally adopted there will be no longer any excuse for fighting poor working furnaces which contain dirt accumulations.

Blast-furnace managers to-day are not writing many articles—they are all too busy with their troubles to write about them, and for this reason there is not as rapid an improvement in blast-furnace practice as there should be. Many men are troubled with problems that have been solved by their neighbors.

In Germany the blast-furnace managers meet frequently and have papers on various subjects, by both theoretical and practical men. They also visit works in a body. It is to be hoped that something of the kind can eventually be attained in this country. In the meantime it is extremely desirable that someone should start to make scientific experiments in regard to blast-furnace lines. No private individual can afford to do this work. It would seem, however, a very good investment for the largest blast-furnace interests.

Warwick Iron & Steel Company,
Pottstown, Pa.

Metallic Sodium from Fused Sodium Chloride.

BY C. F. CARRIER, JR.

During 1904, the author commenced a study of the art of separating metallic sodium. This investigation was carried on for two years and published in the form of a critical, bibliographic summary in ELECTROCHEMICAL AND METALLURGICAL INDUSTRY, v. 4; p. 442 and 475 (1906). In this same period the Castner sodium process was experimentally tested, and a proposed process of H. Becker thoroughly investigated on a laboratory scale. (*Electrochem. Ind.*, v. 2; p. 357 (1904) and *Zeit. f. Electrochemie*, v. 10, p. 568 (1904). The most important result of this latter investigation was that the temperature permissible in the electrolysis of fused caustic soda is considerably raised by the addition of sodium carbonate to the electrolyte.

As a result of these investigations and researches, it was concluded that the Castner process had attained about all that could be expected from the electrolysis of fused caustic soda. The history of the efforts to produce sodium by the electrolysis of fused sodium chloride did not offer any encouragement in that direction, but still the cheapness of the raw material and the directness of the process made it the most inviting line of attack.

The Acker process had demonstrated that sodium-lead alloy could be produced on a large scale with good efficiency by electrolyzing fused sodium chloride in the presence of a melted lead cathode. This suggested the possibility of using the preparation of the sodium-lead alloy as an intermediate step in the preparation of sodium. In 1903, Prof. J. W. Richards suggested to his students the possibility of refining metals by using the impure metal as a fused soluble anode in a fused electrolyte and plating the desired metal over to the cathode in the fused condition. The same idea has been advanced by

Borchers for the refining lead (*Zeit. f. Electrochemie*, v. 1; p. 13 (1894), and also by Hoopes for refining aluminum (U. S. P., No. 673,364 of 4-30-01).

From the above observations were evolved the general lines of a possible solution of the difficult problem of obtaining sodium from fused sodium chloride. If the Acker furnace were to be so modified that the lead-sodium alloy could be passed into a second compartment and there made a soluble anode in a fused electrolyte that would not consume the sodium, it would seem possible to recover the sodium at the cathode. This would make a furnace analagous to the Castner caustic cell, fused sodium chloride replacing the brine, melted lead performing the function of the mercury and the sodium being liberated in a fused bath instead of being allowed to react with water to form caustic.

This idea also forms the basis of the apparatus devised by E. A. Ashcroft (U. S. P. No. 788,506 and No. 801,199, *Trans.* Am. Electrochem. Soc. v. 9; p. 123, 1906, and *Electrochem. & Met. Ind.* v. 4; p. 145, 1906). The investigation to be described below was abandoned for financial reasons before entirely completed, but such a favorable state of development was reached that the conclusions are of value as well as of general interest, and are made public at this time through the courtesy of the Elmira Electrochemical Co.

Preliminary Trial.

A small laboratory apparatus was constructed in the laboratory of the Technische Hochschule zu Karlsruhe in 1904. This consisted of a sheet iron box about 12 in. x 4 in. x 3 in. deep, divided into three compartments by sheet partitions reaching nearly to the bottom. Each compartment was provided with a sheet iron shell whose lower edge was about twice as far from the bottom of the box as the lower edges of the partitions, and which were of such size that about ½ in. space was left between the shell and the sides of the compartment. This space was filled with Portland cement, leaving an opening beneath the partitions.

The box was mounted on a fulcrum and eccentric so that it could be rocked in the same manner as the Castner caustic cells. The bottom of the box was filled with sufficient melted lead to form seals below the partitions and a gas burner was provided to keep the contents melted. All three compartments were filled with melted caustic soda, the two end ones being the anode compartments and the middle one the cathode compartment. The capacity of the apparatus was about 50 amperes.

Only a few trials were made with this apparatus, for the results could not be conclusive either for or against. The cement fouled the electrolyte, causing objectionable foaming and unsatisfactory operation generally. Sodium was liberated at the cathode but from the conditions of the experiment, it would be difficult to prove whether the caustic in the anode compartments was the real source or not. Very little gas was evolved at the cathode, which is not the case in the simple electrolysis of fused caustic, therefore it was assumed that a portion at least of the sodium was being produced according to the theory of the process. It was, therefore, determined to test the process on a commercial scale and the above mentioned company was formed for the purpose of erecting and operating an experimental plant.

Electrical Equipment.

It is impracticable to treat fused sodium chloride on a small scale, therefore a dynamo of 1000 amp. capacity was secured, although in the light of experience 2000 amp. is to be preferred. The dynamo was seperately excited by means of a small 110-volt dynamo. Regulation was partly obtained by a speed controller on the motor driving the dynamo, but chiefly by regulation of the field of the exciter, in series with which was a rheostat and a bank of incandescent bulbs. In this manner the voltage could be varied from 2 to 16, the capacity being 10 kw. The main circuit was provided with a 1000-amp. ammeter and a voltmeter. There was also a shunt circuit with a capacity of 300 amp. and a corresponding ammeter. By means of a water-pipe rheostat, the amount of current passing through the cathode compartment could be regulated according to the efficiency of the operation of the anode compartment as will be explained below.

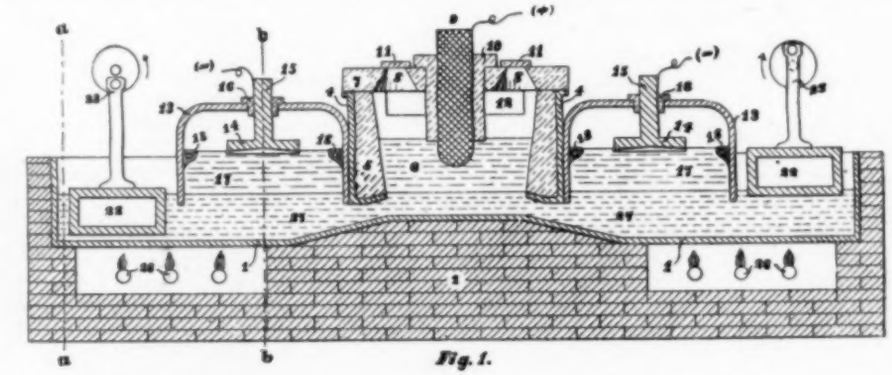


Fig. 1.

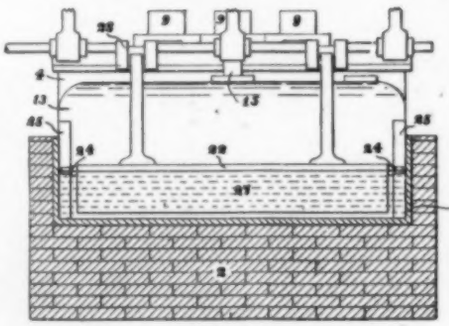


Fig. 2.

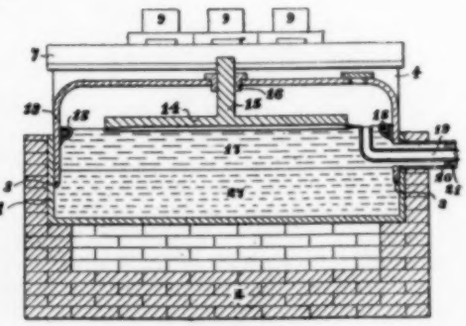


Fig. 3.

FIGS. 1, 2 AND 3.—PISTON TYPE FURNACE.

Piston Type Furnace.

This furnace was designed for 800 amp. capacity, allowing a margin for possible increase in the current density without overloading the generator. The general features of this type will be more clearly understood from the illustrations, Figs. 1-3, from U. S. P. No. 830,051, but some modifications were made in the experimental installation, which will be specially noted later. The apparatus will first be described as planned. The changes and reasons therefor will be described in detail, thus marking the progress of the research.

Fig. 1 is a longitudinal, vertical section. Figs. 2 and 3 transverse vertical sections on the lines *aa* and *bb* respectively in Fig. 1, looking to the right. A rectangular, cast-iron pan 1 is set in masonry 2. The other portions of the apparatus up to 18 inclusive are supported within the pan by shoulders 3. Over the raised portion of the pan is located the anode compartment, enclosed by a cast-iron frame 4, which is lined with fire brick 5, which will withstand the fused electrolyte 6.

The cover 7 consists of a cast-iron frame filled with a fire-clay concrete composed of broken brick, fire clay, and a little cement. Feed holes 8 and openings for the graphite anodes 9

are also provided. To protect the anodes from oxidation, they are protected by means of earthenware sleeves 10. The feed holes are covered with simple slabs 11. A port 12 located at the back of the anode compartment carries off the gases formed. The two cathode compartments are in the form of an inverted, rectangular, cast iron box, opening downward, forming a sort of bell 13. The cathode proper is an iron plate 14 supported by heavy lugs 15, which are insulated from the bell by an insulating sleeve 16.

To prevent the current from flowing from the cathode to the bell, a portion of the electrolyte 17, is solidified by means of the cooling pipe 18, through which water is circulated. The pipe 19 for removing the metal produced is insulated from the other parts of the cathode compartment. The melted lead cathode 27 is circulated by means of the pistons or floats 22 which are raised and lowered alternately by means of the cranks 23. (To reduce the cost of construction, the pistons in the experimental furnace were operated by a walking beam instead of by cranks.)

As already noted, the operation of the furnace is analogous to the Castner caustic cell. The fused sodium chloride is decomposed by the current yielding chlorine at the anode and lead-sodium alloy at the cathode. The circulation of the alloy carries the sodium to the cathode compartment where it is dissolved out of the alloy by the ions liberated at the surface of the alloy which here acts as anode, and the sodium is liberated at the cathode. The electrolyte in the cathode compartment is not decomposed at all ultimately, simply serving as a medium for the current to transport the sodium from the anode to the cathode. The circulation of the lead is facilitated by the raised bottom of the pan. The constriction of the path of flow increases the velocity of flow beneath the anode compartment and thus gives a positive transfer of the alloy from one compartment to the other.

In the furnace as constructed the pan 2 was 5 ft. long by 3 ft. wide. The anode compartment 28 in. x 13 in. x 9 in. high (internal). The cathode compartment 28 in. x 8 in. x 4 in. high (internal). Pistons 26 in. x 7 in. x 4 in. (external). Stroke 2½ in. Displacement, 450 cu. in. per stroke. The anodes consisted of 5¼ in. diameter by 4 in. long heads screwed onto 3 in. diameter rods, which in turn were screwed into a heavy cast iron head to which the cables were attached. There being three such heads, the total anode surface parallel to the cathode was about 420 sq. cm. (65 sq. in.). The cathode surface was about 2350 sq. cm (364 sq. in.). (This ratio is too large. In practice the cathode surface should not be any larger than the anode surface than can be helped.)

Mr. Acker states 295 amp. per sq. dm. as the current density at the anode in his furnace. The density in this furnace will be 190 amp per sq. dm. using 800 amp and and 235 amp per sq. dm., using 1000 amp. There is a maximum limit to the current density on graphite anodes in a fused bath of sodium chloride. In one experiment using 800 amp. on two of the above heads, a current density of about 300 amp. per sq. dm., it was found that the graphite was very rapidly corroded.

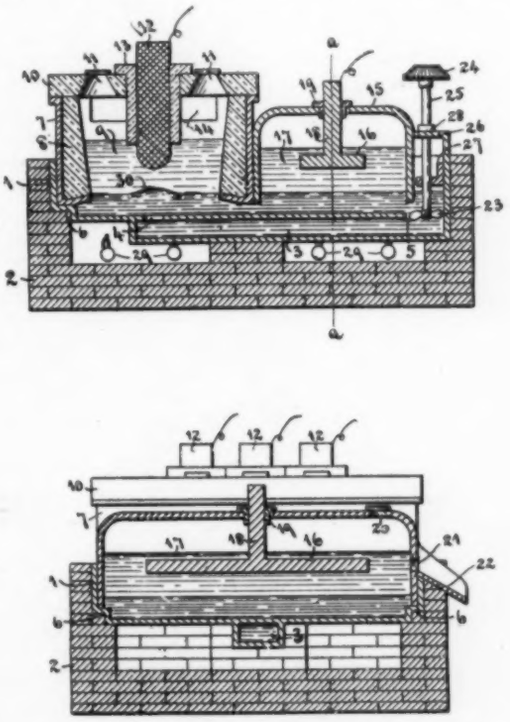
The gas burners were made on the principle of the Bunsen burner, on a greatly magnified scale. The gas supply tube was ¾ in. diameter and the outer tube 3 in. diameter by 24 in. long. The air was supplied by a fan. With natural gas, the whole furnace could readily be heated to a full red heat.

The piston type of furnace was only operated for a short time and not being successful was soon abandoned for the following reasons: (a) Excessive radiation loss: It will readily be seen from the illustration and description that the superficial area covered was comparatively large. The gas burners were only intended to heat up the furnace on starting, the heat being afterward maintained by the electric current, but it will be noted that while the area of the anode compartment, where the greater part of the heat is generated, is only 364 sq. in., the total area of the furnace is about 15 sq. ft. This loss alone was sufficient to kill the commercial possibilities of the furnace, but even greater difficulties developed.

(b): The piston circulation itself was a total failure. It being impossible to make a tight joint between the piston and the sides of the pan, a narrow rim was left which exposed a strip of the surface of the red hot lead. The melting point of litharge is above the temperature of the lead in the furnace and therefore it solidified in the space between the pistons and the side. The solid crust was lifted at each elevation of the piston, exposing a fresh surface of lead, until finally so much litharge had accumulated that the apparatus was brought to a standstill. Reciprocal circulation is also not recommended, as the reversal of the flow makes it impossible to obtain the desired velocity of flow under the anode compartment. It requires a strong, positive flow to maintain a clean metal surface at the cathode and this is more readily obtained by means of the improved furnace described below.

Continuous-Flow Furnace.

To overcome the difficulties mentioned above, an entirely new type of furnace was constructed. The piston circulation was abandoned, thus rendering it possible to make the furnace more compact, with a corresponding reduction in the radiation loss. Continuous circulation was substituted for the reciprocating movement in the piston type. The general features will be readily understood from Fig. No. 4 and No. 5, from U. S. P. No. 859,431 of 7-9-07.



FIGS. 4 AND 5.—CONTINUOUS-FLOW FURNACE.

Fig. No. 4 is a longitudinal, vertical section and Fig. No. 5 is a transverse, vertical section on the line *aa* in Fig. No. 4. The cast-iron pan 1 is set in masonry 2. On the under side of the pan, and cast with it, is a longitudinal compartment 3, communicating with the pan through the circular openings 4 and 5. This forms a return passageway for the fused lead. The opening 4 is arranged axially with one of the anode heads and each anode head has a corresponding opening from the lead conduit. The remaining portions of the apparatus are supported within the pan by means of the lugs 6. The anode and cathode compartments are constructed in the same manner as described under the piston type.

At the end of the apparatus, beyond the cathode compart-

ment, is located the circulating device. This consists of the screw propeller 23, which is rotated in the opening 5 leading into the compartment or passage 3, by means of any suitable power-transmitting device, such as the gear 24. The same gas burners were used as in the piston furnace. The general action is the same as already described for the piston type.

Some small changes were made in the construction which do not exactly correspond with the figures given in this article. Two anode heads were used instead of three, the dimensions being the same as already given. The charging opening was in the front instead of in the top. The anode surface parallel to the cathode was 280 sq. cm. (43 sq. in.) and the cathode area about 1560 sq. cm. (242 sq. in.). On the basis of 800 amp. for the piston furnace, the new furnace was rated at 500 to 550 amp., but was found afterward to work better at a higher density, 600 to 700 amp. being usually used.

About 1400 lb. of lead were required to fill the furnace up to the seals under the edges of the compartments. The circulation was efficiently accomplished by means of a cast-iron propeller 4 in. in diameter, revolving 600 per minute. While the desired vigorous, positive circulation was readily obtained, this arrangement is not recommended for practical operation owing to the frail nature of the propeller. A tangential pump would work equally well and could be made sufficiently massive to withstand the rough usage involved in pumping red hot lead.

The great advantage of this type over the one abandoned rests in the circulation of the melted lead cathode. The strong current of fluid metal rises through the openings beneath the anode, forming a sort of mound on the surface, from which the flow radiates in all directions.

In this manner the surface of the cathode is kept perfectly clean, which is quite essential to the success of the operation. If this is not done, a difficultly fusible layer will coat over the cathode and abnormally raise the resistance of the electrolyte. This layer contains graphite dust torn away from the anode and the difficultly fusible impurities in the salt, as sulfate of lime. In time this layer, which is in a pasty condition, will stop the action of the furnace.

If, however, the circulation is accomplished as described above, the strong radial currents will carry the impurities to the sides of the compartment, where they will accumulate in a thick layer, which may be removed from time to time. In experiments with the piston furnace, where the circulation was weak, the operation was several times brought to a halt by this accumulation spreading over the entire cathode surface.

In starting, the furnace was first heated to a full red heat by means of the natural gas burners. This heat is not sufficient to melt the salt which is accomplished as described by Acker, *Trans.* Am. Electrochem. Soc., v. 1, p. 169 (1902). This consists in passing a strong current through a resistor until sufficient melted salt has been formed so that the electrolyte can carry the current. The resistors were ¾ in. or 1 in. diameter carbons, about 3 in. long, driven into the face of the anode blocks.

The resistors were heated to a bright red heat and the salt piled around them. Two resistors were usually used, one on each anode head. The 1 in. x 3 in. rods would carry 400 to 500 amp. at 4 to 5 volts and the ¾ in. x 3 in. rods, 300 to 400 amp. at 5 to 6 volts. After a time a pool of melted salt will form.

The resistors may then be broken off and the current started through the electrolyte. It is essential that the graphite anode be red hot before the resistors are broken off, for the melted salt will not "wet" the cool graphite surfaces; or in other words a thin layer of solid salt forms on the cold graphite and being a non-conductor no contact can be obtained.

The preparation of the original bath, especially in experimental work, is facilitated by using a mixed electrolyte instead of the pure salt. A mixture of 3 molecules sodium chloride, 3 molecules potassium chloride and 2 molecules of calcium chloride melts readily at a red heat and will yield almost pure sodium on electrolysis, a small percentage of potassium being liberated with the sodium, but no calcium. After the current has once been started through the electrolyte, only salt need be added for this purpose only the very purest commercial salt obtainable is to be used, as the impurities form the infusible material mentioned above, which has to be removed. Mined rock salt is usually the best.

The furnace as described above may be used in the preparation of free metallic sodium or in the preparation of sodium compounds which ordinarily involve the use of metallic sodium at high temperatures. If sodium is desired, the electrolyte in the cathode compartment must be of such nature that it will not be decomposed by sodium at a full red heat.

As the present commercial process for obtaining sodium is based on the liberation of the metal in a fused bath of caustic soda, this compound was naturally the first one selected as the electrolyte for the cathode compartment. It was then a matter of considerable surprise when it was found impossible to obtain any trace whatsoever of sodium when the attempt was made. It was first thought that the fused caustic still held some last traces of moisture even at a red heat, but in this case there should have been at least a liberation of hydrogen. The electrolyte simply laid dead in the furnace and not a bubble or a globule of metal was formed to show that 400 to 600 amperes were being passed through.

The writer is not prepared to state positively that it is impossible to liberate sodium from fused caustic soda at 700 to 900° when the anode is soluble and contains sodium, but the indications from these experiments are that such is the case. The electrolyte was not wholly protected from the action of the air and it is possible that sodium reacted with caustic at this temperature to form a suboxidized compound, which took up oxygen from the air. However, it was thought best to avoid the presence of oxygen in the electrolyte.

As pure sodium chloride is so difficult to melt, the cathode compartment was filled with the same mixed chloride bath described above for use in starting the fusion in the anode compartment. As soon as the lead cathode had had an opportunity to take up sufficient sodium to supply the sodium required for the soluble anode, the current was started through the cathode compartment and regulated by the water rheostat so that only 75 per cent of the total would be acting in that comparment. As soon as the current is started the globules of metallic sodium begin to gather on the surface of the electrolyte.

The conditions under which the experiments were carried out were such that it was impossible to continue a single continuous experiment for a sufficiently long period to gain any reliable data on the ampere efficiency and for the same reason no fully satisfactory method of removing the red hot sodium was devised. It might be safe to assume that the ampere hour efficiency would equal the 93 per cent claimed for the Acker furnace (*Trans.* Am. Electrochem. Soc., v. 1, p. 171, 1902), but as some sodium is lost in removal from the furnace, 80 per cent was assumed as the basis of commercial calculations. The voltage was 6 to 8 volts using 500 to 700 amp. The experiments were finally stopped for financial reasons.

A few experiments were also made on the preparation of sodium compounds instead of the metal. Two important compounds requiring the free metal in their preparation are sodium peroxide and sodium cyanide. It was hoped that by liberating the sodium in a fused bath of caustic in the presence of air at a bright red heat that both the caustic and the sodium produced would be converted into a mixture of sodium oxide and sodium peroxide which by further heating in air could be entirely converted into the peroxide. Sodium nitrate was also used as an oxidizing agent in some of the experiments.

No conclusive results were obtained but it was found that the percentage of sodium oxide in the bath increased as the experiment progressed and the product would liberate oxygen

when placed in water. This product was so impure, however, that it was feared that it would not be able to compete with the high-grade material made from the previously prepared sodium.

It was impossible for reasons stated to carry the experiments further but it had been demonstrated that it was possible to produce sodium compounds by electrolysis in a fused bath with a soluble anode containing sodium, the bath being capable of uniting with sodium to form the desired compound. It is to be noted that these compounds cannot be prepared from lead-sodium alloy and reacting upon this with similar reagents, the method described being equivalent to the use of free sodium while the lead-sodium alloy is not.

This is due to the fact that the formation of the alloy is strongly exothermic and therefore a corresponding amount of energy is required to liberate the sodium from the lead before it can react. In brief, it is possible by this method to produce compounds of sodium ordinarily requiring the use of previously prepared sodium, without the expensive operation of obtaining the metal in ingot form.

In conclusion, it may be said that while these experiments left the problem in a partly developed condition, they fully demonstrated the possibility of preparing both metallic sodium and sodium derivatives along the lines described. With the experience gained, it would be possible to modify the apparatus as suggested above and complete the demonstration of the commercial feasibility of the processes, but no further funds being available the work had to be abandoned.

Temperature Coefficients of Resistance of Resistors.

Since nickel and nickel-chrome (the latter, for instance, under the trade name nichrome) are often used as resistors for electric heating or electric furnace work, the measurements of their temperature coefficients of resistance, as given by A. A. Somerville in a recent American Physical Society paper, should be of interest. (See *Physical Review*, February, page 268.)

Four materials were studied—nickel and nichrome, two good furnace wires, inasmuch as they do not oxidize readily; and tungsten and molybdenum, which must be protected from oxygen when heated. The nickel and nichrome curves are very similar in shape, but the coefficient of the former is 20 times that of the latter. The coefficients in either case are relatively small between 400° C. and 1000° C. as compared with the coefficients outside these limits. (Unfortunately, the exact numerical figures are not given.) The tungsten and molybdenum curves are slightly convex toward the temperature axis. The coefficients are large—1 ohm of molybdenum at 0° C. measuring 5.7 ohms at 1000° C. and 1 ohm of tungsten at 0° C. measuring 6.9 ohms at 1000° C.

Silica Standards of Length.

Silica standards of length are quite a novelty. As mentioned in the recent annual report of the (Brit.) National Physical Laboratory, careful experiments have demonstrated that silica is superior to glass as to thermal hysteresis, the coefficients per degree Centigrade being: Silica, from 0.5 to 1; Jena glass, 59^{III}, 2.7; Jena glass, 16^{III}, 3.5, all expressed in 10^{-7} units. The 1-m silica standard of the National Physical Laboratory is a tube supplied by the Thermal Syndicate, 2 cm in diameter, having half disks fused into its ends.

The difficulty of getting good defining lines on the silica has been overcome. Ordinary scratches chipped off in a day or two, and could not be seen when the tube was immersed in water. The ends have, therefore, been platinized, but on the lower surface; the graduation is cut through the platinum film into the silica, and the protecting glass cover rests against the lower platinized surface. The reading from above is, therefore, not affected by any tilt in the cover glass.

High-Temperature Gas Thermometry and Its Present Limitations.

BY ARTHUR L. DAY.

The measurement of temperature is different from most ordinary measurements. There is no temperature unit corresponding to a foot rule or meter stick which can be applied successively to measure an unknown temperature as we would measure the height of a room. Two temperatures of 1° cannot be combined in any way to give a temperature of 2°. Temperature measurement is, therefore, wholly a matter of arbitrary definition, of selecting some convenient phenomenon like the expansion of gas which varies continuously and uniformly (as nearly as possible) with temperature changes, of providing convenient arbitrary units of subdivision and then of observing its behavior under the same conditions which surround the unknown body whose temperature is desired. The expansion of hydrogen has been established by international agreement as our fundamental measure of temperature. The gas thermometer is, therefore, now the standard thermometer in terms of which all temperatures are expressed.

The theoretical interest in gas thermometry centers about the quantitative relation existing between the increase in the temperature of the gas at constant pressure or volume and the quantity of heat required to produce it. It is a somewhat inaccessible question by reason of the difficulty of approaching it experimentally with the required accuracy. Although the amount of the expansion of gases is more closely proportional to the quantity of heat applied than that of other substances, no strictly "perfect gas," in this sense, has been found.

The amount of the divergence in the case of nitrogen, which has a greater range of practical utility than other gases thus far studied, is of the order of magnitude of a single degree of 1100° C., and the uncertainty in this correction factor is probably smaller than the observation error of a practical gas thermometer in the present stage of its development. For this reason these theoretical considerations, which have been admirably treated by Buckingham in a paper, "On the Establishment of the Thermodynamic Scale of Temperature by Means of the Constant Pressure Thermometer" (*Bulletin* Bureau of Standards, 3, 237, 1907), do not seriously affect the definition of an accurate and practical high-temperature scale by means of the gas law.

On the other hand, there is no denying the fact that a great deal still remains to be done upon the experimental side before the steadily advancing requirements of both science and industry in the matter of a trustworthy temperature scale of sufficient accuracy, and even more particularly, of sufficient range, can be satisfied. It is no disparagement of the present system of temperature definition to say that the gas thermometer itself is a complicated and cumbersome instrument to use in any of the forms which have hitherto been devised, and possesses limitations both of range and of accuracy which are difficult to overcome.

One consequence of this, particularly in the region of high-temperature measurements, is that temperatures easily come to be regarded with unwarranted confidence in the hands of those who have never acquired a first-hand knowledge of these limiting conditions. This has been further facilitated by the comparative ease with which relative measurements of temperature can be made, even in the more inaccessible parts of the scale, with the thermoelement and the resistance thermometer. These devices are sensitive to temperature differences of the order of magnitude of 0.01° throughout their entire range, but they are dependent absolutely upon fundamental measurements with the gas thermometer for their evaluation in terms of the generally accepted degree Centigrade.

It is sufficiently obvious, though often carelessly overlooked, that no method of temperature measurement, however sensitive or adaptable it may be, can yield temperatures of greater abso-

lute accuracy than the system in terms of which those temperatures are defined. With the gas thermometer as our basis of definition, therefore, we shall know our temperatures with just the certainty which it is able to furnish and no more. There is, to be sure, some justification for expressing the results of thermoelectric or resistance measurements in units smaller than the errors of the fundamental scale, where only comparative measurement is involved, but such measurements must not be allowed to escape from this limitation.

It is not the purpose of the present article to discuss the general problem of thermometry or the particular advantages of one system of thermometric measurement over another in laboratory or industrial practice, but merely to speak very briefly of some of the work which has been done in recent years to increase the range and accuracy of the temperature scale upon which the various devices for measuring high temperatures depend for their calibration. Neither is it necessary in so brief a review to include any discussion of the relative theoretical merit or experimental practicability of the constant-volume and constant-pressure methods of gas thermometry. The reader will find it in Buckingham's paper already mentioned, as well as in earlier discussions to which he refers. The choice of the one or the other method is likely to be governed by the taste or predilection rather than by the necessities of the individual experimenter. Neither system possesses decided advantages over the other. All the recent measurements (including all those referred to in this paper) have been made with the constant-volume system.

By international agreement and nearly universal practice, two fixed temperatures are accepted as the basis of the modern temperature scale, the melting point of pure ice and the boiling point of pure water, both at normal atmospheric pressure (760 mm of mercury). The interval included between these two temperatures is subdivided into 100 parts by measuring the constant volume expansion of hydrogen from an initial pressure of 1 m of mercury throughout this interval.

The actual determination of these intervals or degrees Centigrade was made by Chappuis at the Bureau International du Poids et Mesures at Paris in 1888, and is a work of such extraordinary painstaking character in most particulars that no investigation has found it necessary to repeat it since that time. The probable accuracy of the individual degrees thus determined, i.e., of the international scale of temperatures between 0 and 100°, is stated by Chappuis to be 0.002°.[1]

To extend the scale beyond these limits in either direction it is (theoretically) only necessary to continue the measurement of the expansion of hydrogen, under the same conditions, down to or up to any desired temperature. In practice, this procedure encounters various experimental difficulties which increase rather rapidly as we get further away from the temperatures of everyday life.

These experimental difficulties serve to place definite limits upon the accuracy of temperature measurements at present attainable in different parts of the field, of which it is important to obtain a clear idea in order to be able to form a sound judgment of the probable significance of measurements at widely different temperatures. If we are told, for example, that a solution boils at 90.27°, we recognize that this accuracy is entirely practicable. If, on the other hand, platinum is said to melt at 1755.46°, it is of advantage to know that the last two figures are wholly without significance and the fourth is uncertain.

There is another reason for being especially explicit upon this point, for very few men in this country have ever made the laboratory acquaintance of the gas thermometer.[2] In its modern form the constant-volume instrument includes five principal features which will be briefly considered with particular reference to the limitations which they severally impose upon the accuracy of high temperature measurements: The gas (1) is contained in an impervious vessel or bulb (2) which is heated in an electric furnace (3) arranged to provide the utmost attainable uniformity of temperature about the bulb at all temperatures. A mercury manometer (4) measures the gas pressure within the bulb, and thermoelements (5) are used to transfer the gas thermometer temperature to standard melting points for general application. These will be briefly treated in order:

(1) The Gas.

The first limitation to the upward extension of the gas scale is a direct result of the choice of a gas. Hydrogen was chosen because it approximated more closely to a perfect gas in its behavior than any other, but the experimental development of the subject has since demonstrated that no vessel can be depended upon to hold it without loss above 300°, so that nitrogen has come to be very generally substituted for hydrogen at the higher temperatures.

With reference to the situation created by this substitution, a long series of comparative measurements by Jaquerod and Perrot,[3] using air, nitrogen, oxygen, carbon monoxide, and carbon dioxide, shows no measurable differences in the behavior of these gases for thermometric purposes up to the melting temperature of pure gold (1062°), but some of these certainly could not be carried far beyond this temperature without danger of serious error through dissociation.

Nitrogen has been used, both in the Reichsanstalt and in the Geophysical Laboratory, as high as 1600° without any appearance of irregularity in its expansion or evidence of dissociation. The extension of the hydrogen scale by the use of nitrogen above 300°therefore encounters no serious difficulty up to the present limit of measurement (1600°) except in so far as it may prove necessary to make a small correction (of the order of magnitude of 1° at 1000°) for reference to the true thermodynamic scale if it is desirable to express the results of measurement in terms of it.

(2) The Bulb.

The bulb is perhaps the most important single element in a constant-volume gas thermometer. The progress of gas thermometry during nearly 100 years has been closely associated with and dependent upon improvements in the bulb. The first bulbs were made of metal (Prinsep used a gold bulb in 1827), and there is little question to-day but that their abandonment for porcelain in 1857 (Deville and Troost) constituted a step backward which was not retrieved for 40 years. The bulbs in use at the Reichsanstalt up to 1897 were still of porcelain, as were those used by Barus throughout his epoch-making work.[4]

Porcelain, glazed or unglazed, violates both essential conditions for a good gas thermometer bulb at high temperatures: (1) It cannot hold the expanding gas without absorbing or losing any of it; and (2) it is not absolutely uniform in its own expansion and contraction. Bulbs of platinum containing 10 to 20 per cent of iridium for additional stiffness were used at the Reichsanstalt in 1900 for temperatures as high as 1200°, and one of pure iridium was successfully carried to 1600° in 1907. These bulbs are still in use.

The Geophysical Laboratory began its work with a 10 per cent platin-iridium alloy, but abandoned it for platinum con-

[1] In a recent paper, "Some New Measurements with the Gas Thermometer," *Amer. Jour. Sci.* (4) 26, 405-463, 1908, the authors gave it as their opinion that the determination of the expansion coefficient of the thermometer bulb used by Chappuis, which is, of course, an important factor in the experimental problem, would not warrant an assumption of accuracy greater than 0.005°. To this Chappuis replied in a personal letter (1909) that, considering all the factors of the problem and subsequent experience, he still thought 0.002° a fairer estimate of the probable error of the scale in the region between 0 and 100°.

[2] An incident may serve to illustrate the fact that the gas thermometer is but a name to a great many otherwise well-informed scientific men. Soon after the appearance of one of the writer's earlier papers upon the subject, a well-known engineer wrote to inquire the cost of a dozen gas thermometers, to which I was under the necessity of replying that I knew of but one in this country, and this one had cost us upwards of four thousand dollars to date and might cost even more before we had finished with it.

[3] Jaquerod and Perrot, *Arch. d. sci. phys. et nat.* Genève (4), 20, pp. 28, 128, 454, 506, 1905.

[4] Carl Barus, "On the Thermoelectric Measurement of High Temperatures," *Bull.* 54 (1888), U. S. Geol. Survey.

taining 20 per cent of rhodium, for reasons which will appear in connection with the use of thermoelements below. All these metal bulbs can be used with nitrogen up to 1600° without appreciable error in the return to 0° after heating, provided only that proper precautions are taken against mechanical strain and consequent volume change at the higher temperatures where the metal is soft.

Porcelain bulbs when unglazed are not gas tight; glazed within, they can be used up to 1100° without serious error, but the glaze becomes soft above this temperature and reacts to some extent with the gas in the bulb which then never returns to its initial pressure at 0°. Porcelain bulbs with outside glaze only were employed by Barus up to 1400° with fair success, but it proved impossible to permanently saturate the bulb wall with the gas, so that it would return to the same zero after heating.

Pure silica bulbs which have recently been introduced by Jaquerod and Perrot (loc. cit., 1905) have an advantage over the metals through their low expansion coefficient, but cannot be used above 1100° without permanent volume changes.

In view of the other improvements which have been made in recent years (notably, the introduction of electric furnaces), it is difficult to estimate the proportion of error in the earlier measurements for which the porcelain bulbs were responsible. Barus' value for the melting point of gold (1888—porcelain bulbs) was 1092°, Violle's (1889—porcelain bulbs), 1035°; Holborn and Wien's (Reichsanstalt, 1895—also porcelain bulbs), 1027°; Holborn and Day's (Reichsanstalt, 1900—platin-iridium bulb), 1063.5°; Day and Sosman's (Geophysical Laboratory, 1910—platin-rhodium bulb), 1062.4°.

(3) The Furnace.

Improvements in the furnace have twice contributed materially to the advancement of gas thermometry: (1) Through the substitution of electricity for gas as a source of heat (Reichsanstalt, 1899), which greatly reduced the uncertainty in temperature distribution over the bulb surface and eliminated the possibility of furnace gases passing into the thermometer itself through the bulb wall; and (2) when the bulb and heating coils were enclosed in an air-tight bomb (Geophysical Laboratory, 1908) under conditions such that the air pressure outside of the bulb could be kept under control and always maintained equal to the pressure of the expanding gas within.

This second improvement made it possible to relieve the bulb from mechanical strain at high temperatures where the metal is soft and susceptible to volume changes, and considerably increased the effective range of the instrument in the high temperature region. It also became possible to use different initial pressures within the thermometer bulb in order to evaluate the pressure coefficient of the expanding gas and to vary the sensitiveness of the instrument.

Before this improvement was made it was necessary to select an initial gas pressure such that the final pressure at the highest temperature to which it was expected to attain would be approximately equal to the atmospheric pressure without, in order that the difference in pressure within and without the bulb should be a minimum when its power to withstand such a difference was smallest. The practical effect of the earlier arrangement was to crowd the entire range of the instrument into ½ m of the manometer scale, giving about ¼ mm per degree. With the air-tight furnace bomb we were able to increase this sensitiveness to a full millimeter for each degree.

To the introduction of electric heating we owe the extension of the range of the gas thermometer from 1150° to 1500°; to the control of the gas pressure about the bulb, a considerable (perhaps five-fold) increase in its accuracy in this region.

With electric heating, the furnace temperature is always under control and readily measurable, but in pursuing high standards of accuracy we must distinguish between a constant furnace temperature of irregular distribution and a variable temperature. The substitution of electricity for gas has given us a constant temperature, but it is not always easy to provide that it shall also be perfectly uniform.

Various baths are available up to perhaps 700° for the purpose of equalizing the temperature about the bulb by interposing between it and the heating coil a liquid layer which can be stirred, but higher temperatures have had to depend upon direct exposure to the radiation from the coil. In the Reichsanstalt instrument, temperature differences of from 10° to 30° were observed between the middle and ends of the bulb in the region 1500°-1600°; in that of the Geophysical Laboratory, the maximum differences were diminished to 2° in the same region.

For greater uniformity than this some form of liquid bath will require to be devised for use at these temperatures also. Such a search might prove worth while, for this uncertainty (in the distribution of temperature about the bulb) appears to be the largest remaining in gas thermometry up to 1550°.

(4) The Manometer.

The manometer contains few factors which affect the ultimate temperature readings materially. The arrangement commonly adopted, both in Europe and in this country, is the open U-tube type in which the difference in the mercury level between the two arms of the U-tube represents the difference between the gas pressure within the bulb and the prevailing atmospheric pressure outside, the latter being read on a separate barometer. The minor corrections for temperature of the mercury, gravity, etc., then require to be applied as usual in such cases.

The only real difficulty encountered here has been much reduced in recent years and is no longer dangerous, even at the highest temperatures. The temperature of the capillary connection between the bulb and manometer varies all the way from the extreme temperature of the bulb to that of the room and with it the temperature of so much of the gas as it contains. The error from this cause is reduced to an insignificant magnitude by making this connecting volume so small when compared with that of the bulb that its average temperature need only be known within about 10 per cent.

Some laboratory experience is necessary to make this reduction of volume judiciously, for the viscosity of gases increases rapidly with the temperature, so that it is not practicable to restrict below 0.8 mm the diameter of those portions of the capillary which are heated. A smaller diameter here would have the effect of producing a very slow readjustment of pressure in the various parts of the apparatus with every change in the temperature, and the observer would be without adequate assurance that equilibrium had been reached at the time when his reading was made.

The uncertainty which attaches to this connecting volume, together with the changes in the zero point due to the irregular behavior of porcelain bulbs, were among the most formidable of the classic errors of gas thermometry. Both are now practically eliminated.

(5) The Auxiliary Thermoelement.

The fact that the gas thermometer bulb cannot be safely immersed in different substances for the determination of their thermal constant carries with it a considerable amount of incidental but practically unavoidable inconvenience. The usual plan has been (and still is) to place thermoelements in the furnace with the bulb and to determine their electromotive force for a measured temperature. A few observations of this kind suffice to establish an empirical curve for the electromotive force of the thermoelement in terms of the gas thermometer temperatures, after which the thermoelement is available for determinations of temperature under a great variety of conditions.

This procedure is considerably facilitated by the fact that the empirical curve corresponds closely to a simple parabola and three or four comparisons with the gas thermometer usually suffice to establish a parabolic curve which may be interpolated with little danger of an error greater than the errors of the

gas scale itself over long ranges of temperature. Its extrapolation has not turned out so fortunately.

Before the publication of the recent measurements in the Geophysical Laboratory, the region of accurate gas thermometry ended with the temperature 1150°. The common practice for some years has therefore been to measure temperatures beyond that point by extrapolating the parabolic curve out to the desired temperature—often as high as the melting point of platinum (1755°). Extended extrapolation is always a matter of grave uncertainty, but no other convenient method was available, and after all, observations of this kind with the thermoelement could be translated in terms of an observed scale whenever one should be provided. It happens in this particular case that the extrapolation (from 1150° to 1755°) comes out just 50° low at the platinum melting point.

Now that the gas thermometer is able to make direct measurements of temperature up to 1550°, it is merely necessary to include several thermoelements in the furnace with it, to evaluate their temperature curves by direct comparison, and afterward to determine with them a series of standard fixed temperatures like the melting points of metals, minerals, or salts, which are available for general use.

This procedure has been followed in the recent investigation with the results which are tabulated below. The pure metals are readily obtainable and the minerals easily made up, so that anyone may now calibrate his thermoelement by noting its electromotive force at the (known) melting temperature of three or four of these substances, preferably choosing such as will include the region in which he expects to use the thermoelement.

Such a calibration requires to be checked from time to time by repeating one or more of the melting point observations, particularly if the element is exposed to contamination for vapors of other metals. This contamination is particularly disastrous if a thermoelement is exposed to the vapor of iridium, which explains the remark made above, that in our experience a bulb made from an alloy of platinum and rhodium is to be preferred to the iridium alloy in use at the Reinsanstalt.

The standard melting points in the table below are taken from observations by Day and Sosman[5] and include, for comparison, the standard melting points published by the Reichsanstalt in 1900 and now in general use:

Substance	Point	Atmosphere	Crucible	Temperature	TheReichsanstalt Scale
Zinc	Melting and freezing	Air	Graphite	418.2°±0.3	419.0°
Antimony	Do.	Carbon monoxide	Do.	629.2 ±0.5	630.6
Silver	Do.	Do.	Do.	960.0 ±0.7	961.5
Gold	Do.	Do.	Do.	1062.4 ±0.8	1064.0
Copper	Do.	Do.	Do.	1082.6 ±0.8	1084.1
Diopside (pure)	Melting	Air	Platinum	1391.2 ±1.5	
Nickel	Melting and freezing	Hydrogen and Nitrogen	Magnesia and Magnesium Aluminate	1452.3 ±2.0	
Cobalt	Do.	Do.	Magnesia	1489.8 ±2.0	
Palladium	Do.	Air	Pure Magnesia	1549.2 ±2.0	1575.2
Anorthite (pure)	Melting	Do.	Platinum	1549.5 ±2.0	

In addition, the following temperatures were incidentally obtained:

Cadmium	Melting and freezing	Air	Graphite	320.0 ±0.3	321.7
Aluminum	Freezing	Carbon monoxide	Do.	658.0 ±0.6	657.
Platinum	Melting	Air	.....	1755.	

A new estimate of the melting point of platinum, which has not yet been directly determined with the gas thermometer, is included in the above list. It was obtained in this way: There is a remarkably close agreement between independent determinations of the *temperature interval* between the melting points of palladium and platinum:

[5] Loc. cit., p. 161.

Nernst and von Wartenberg[6]	204°
Holborn and Valentiner (at the Reichsanstalt[7])	207°
Waidner and Burgess (at the Bureau of Standards)[8]	207°

If we, therefore, simply add 206° to the palladium melting temperature (1549°), we obtain 1755° as the melting point of pure platinum, with an absolute error of perhaps no more than ± 5°.

By way of conclusion, the following estimate is offered of the accuracy of existing standards of temperature within certain temperature intervals:

0° — 100° ± 0.002°
100° — 300° ± 0.05°
300° — 1100° ± 0.8°
1100° — 1550° ± 2°
1550° — 1750° ± 5°

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C.

Sintering of Fine Ore and a Sintering Machine.*

By Alfales B. Young.

Among the metallurgical developments of the last decade one of the most important has been the sintering treatment of fine ore, which beginning as a step in the reduction of lead, with its chief object the securing of a dead roast, has come to be a prominent factor in copper smelting, where its object other than that of obtaining the roast, is also the preparation of the product in a sintered or agglomerated form suitable for blast-furnace work. The first to bring forth the idea of a blast roast were Huntington and Heberlein, whose names have been so linked with sintering in general that a great deal of it is known under the heading of the "Huntington-Heberlein process," although it does not, strictly speaking, belong to their invention.

In a general way, the process of sintering may be classified in two divisions, viz., those requiring a preliminary roast and those in which the raw ore is sintered directly. The former belong to the Huntington-Heberlein process, and in the latter are the Carmichael-Bradford, the Savelsberg, and the Bormette processes.

The above is only a partial list, but I think it contains the more important methods.

The characteristic feature of the Huntington-Heberlein process is the addition of limestone to a partially roasted galena ore. The fine galena concentrates are mixed with limestone and slag-making material, and this is given a preliminary roast. The first roast eliminates sulphur to the extent of 6 per cent to 8 per cent. The Godfrey rotating-hearth roaster was formerly preferred for this part of the operation, but any of the modern types of roasting furnaces will serve the purpose.

The Huntington-Heberlein sintering pot or converter is shaped like an inverted dome having a diameter of 8 ft. or 9 ft. About 1 ft. from the bottom a grate, convex upward, is fitted in the portion of the pot under the grate, having an opening or tuyeres for attaching an air pipe and thus constituting a wind-box. Over the pot is a hood, attached to a flue or stack, which may be raised out of the way. Usually there is a row of pots over which runs a traveling crane for charging and dumping them.

Prior to charging, a thin layer of coal ashes is spread over the grate. On this is dumped a layer of hot calcines from the roaster, and on this, in turn, the regular charges of calcines, moistened with water. The time of sintering varies from 8 to 14 hours, and a product with about 2 per cent sulphur is ob-

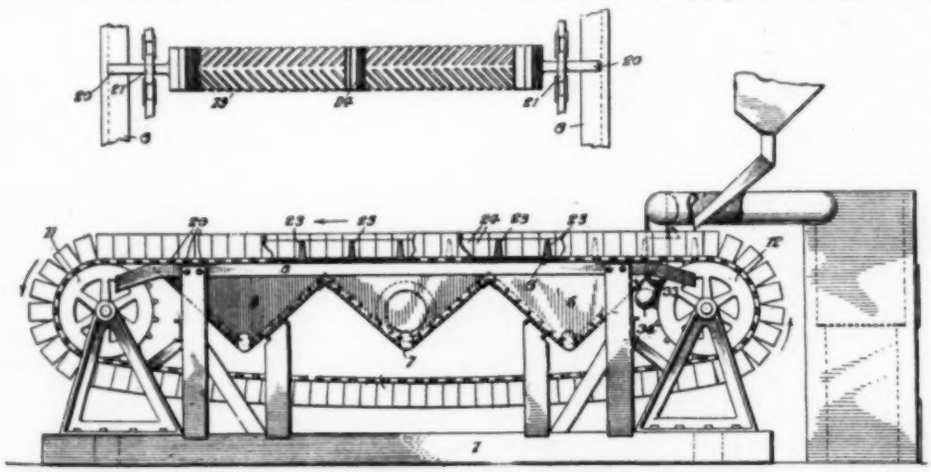
[6] W. Nernst and H. von Wartenberg, Ber. d. Deutsch. phys. Ges., iv, pp. 48, 146, 1906.
[7] L. Holborn and S. Valentiner, Ann. d. Phys. (4), xxii, 1, 1907.
[8] C. W. Waidner and G. K. Burgess, Bull. Bur. Standards, iii, p. 163, 1907.

* A paper read at the Fifth General Meeting of the Western Association of Technical Chemists and Metallurgists and published in the *Western Chemist and Metallurgist*, March, 1910.

tained. The addition of limestone seems to aid the roasting and at the same time prevents a premature fritting before the roast takes place. This is probably accomplished both by a mechanical action of the particles and by absorption of heat in the breaking down of the calcium carbonate molecule into lime and carbon dioxide. The sintering material is dumped from the pot by the crane, where it is sprayed with water and broken up by sledging.

The Carmichael-Bradford process employs dehydrated gypsum instead of limestone. The process is carried on in the same form of pot as the Huntington-Heberlein. The charge at Broken Hill, where this method has met with success, consists, roughly, of one part dehydrated gypsum, three parts of slimes and one part of sand concentrates. The sulphur content of the charge is about 16 per cent and of the product about three. The material for the charge, mixed and moistened in a pug mill, is broken into nut-sized lumps while still wet and spread out and allowed to dry in the sun. The charging of these small lumps enables an extremely free passage of air through the mass, giving a good sinter and lessening the time of the operation.

The Savelsberg process is like the Huntington-Heberlein in that the flux used is calcium carbonate, but differs in the fact that a preliminary roasting is unnecessary. By the addition of sufficient limestone the heat from the oxidation of the contents



APPARATUS FOR SINTERING FINE ORES.

of the charge is absorbed by the breaking up of the carbonate. The sintering pot is of the same general shape as that previously described. However, instead of being manipulated by a traveling crane it is mounted upon a track, much after the fashion of the ordinary slag pot.

The Bormette method of lead and copper smelting consists of the incorporation of the fines in a predetermined amount of liquid slag, accompanied by rapid stirring in the pot. A porous, spongy mass is evolved with about 50 per cent desulphurization. These sintering processes, briefly described, have been gradually taken over into copper work, where mine fines, matte and flue dust have been agglomerated with varying degrees of success. The addition of lime and other kindred substances has practically been eliminated, as the prevention of premature sintering is not required. It has been my experience that the addition of quartz or lime, as the case may be, in such quantities as to give a monosilicate in the slag part of the sintered mixture, gives the best results both in time of sintering and in percentage of charge sintered. With a copper ore running SiO_2 14 per cent, S 27 per cent, Fe 45 per cent, Al_2O_3 4 per cent and lime and magnesia 4 per cent, using a size ½ in. or smaller, I have had success in mixing flue dust to the extent of almost one-third by volume, securing in a Huntington-Heberlein pot a sinter of 85 per cent to 90 per cent of the total charge to 10 per cent to 12 per cent sulphur in seven or eight hours.

The unsintered portion is almost invariably a layer of from 4 in. to 8 in. at the top of the pot. As might be expected, the presence of fairly coarse pieces in the charge is an aid to the action.

The future of sintering as an economic method of roasting copper fines depends chiefly upon the cost of operation plus the cost of smelting in the blast furnace as compared with the cost of roasting in the ordinary way plus the cost of smelting in a reverberatory; and, secondly, the cost of ordinary smelting plus briquetting, as compared with the cost of sintering.

In lead work the Huntington-Heberlein process has proven itself far cheaper than the old lead reverberatory. The best we may say, however, in regard to sintering intermittently in pots is that it is crude. In the first place it is a theoretical waste of capacity for the sintered layers to be dormant in the bottom of a pot waiting for those above to be treated in the operation; secondly, it is a waste of power, having to drive air at a necessarily higher pressure through the layers below in order to reach those above to act upon them; and, thirdly, the handling of the large lumps of sinter is, at best, a clumsy and expensive operation.

The solution of the problem lies in the development of a continuous sintering machine, taking and discharging the sintered material in thin layers. To the solution of the latter part of the problem Messrs. A. S. Dwight and R. L. Lloyd have contributed the down-draft system, in which the air is sucked or blown toward the grate, thus maintaining a lack of movement among the particles and preventing the layers away from the ignition surface from remaining unsintered. This, of course, has its disadvantage in the corrosive, moist, sulphurous gases having to pass through the pipe connection and the suction fan.

To the solution of the former part of the problem I have applied merely the endless-belt idea and erected partitions on the bars of the traveling grate, dividing it into compartments, thus dividing the sinter in blocks of suitable size requiring no further breaking or crushing.

This sintering machine consists essentially of a grate in the form of an endless traveling belt which carries a bed of fines and passes for nearly its entire length over a suction or wind box, by which air is drawn through the mass. Means are provided at one end for distributing the layer of fine material over the surface of the grate and for its ignition, and at the other end the sintered product is discharged into a convenient receptacle.

Referring to the drawings, the grate consists of numerous cast-iron segments (19) carried upon the links of the chains (21) which move upon two pairs of sprocket wheels (11 and 12). The segments of the grate are provided with projecting arms (20) which rest upon rails (8) in order to prevent sagging.

Directly beneath the grate is a wind or suction box (6), to which a suction pipe is attached leading to the suction fan furnishing the draught. The sprockets are mounted upon bearings and the rails and the suction box, etc., upon supports, all of which rest upon the bed frame (1).

On the right hand of the drawing are shown the ignition apparatus and the distributor. The former consists of a small furnace or stove of the reverberatory type, from which the flames are led by a pair of flues around the distributor and into the igniter, which is merely a long sheet-metal box extending

in length the width of the grate and probably 3 in. to 6 in. wide.

This box is, of course, open at the bottom and the flame passes from it directly through the ore. Upon this igniter is mounted the plow (40). Fines from the distributor falling upon the grate are spread out evenly as they travel under this plow. Thus the igniter fits closely to the surface of the ore.

Right under the igniter, and beneath the grate, is a special suction box (33). This is connected to a special suction pipe (34), thereby giving at the point of ignition a very much stronger draught than that of the large section box (6). This insures the first-class priming—the chief essential to good sintering.

Chain.—This would be one of the standard roller chains made by transmission machinery manufacturers. The rollers would carry the chain upon the rail (8) and upon a rail on the under side (not shown) where the grate travels back.

Grate.—This grate is divided into compartments by the centrally located ribs (24) and medial ribs (23) upon every third or fourth segment. These ribs are as high as the top of the layer of ore; thus it is sintered in blocks and requires no subsequent breaking of any kind. Any form of perforation may be used for grate holes, although I have shown a fishbone arrangement, the elongated holes extending across the halves of two segments, thereby breaking in the middle when going around the sprocket and tending to dislodge any accretion which may have formed. These grate segments are so designed that replacing them is a very easy matter.

Suction or Wind Box.—(6) The peculiar shape of the bottom is for the purpose of facilitating the removal, through the handholes of any material which may have fallen through the grate.

Frame.—Although this is shown in the drawing as being of wood, it may be made of structural steel.

Operation.—Fine ore, flue dust, etc., are fed from the bin and feed hopper (diagrammatically indicated) to the machine through the distributor. The layer is spread evenly by means of the plow and passes under the igniter, where a strong flame is sucked through it. It then goes over the suction box, where air is drawn through the mass and roasting and sintering takes place. This continues until the end of the machine is reached, where the grate, turning around the sprocket, breaks away from the sinter, which discharges at this point. Here a spray of water will be constantly playing to cool the blocks.

The speed of the machine will be from 6 in. to 1 ft. per minute; the draught a vacuum of about 5 in. or more of water (3 oz. per square inch). The over-all length of a machine, of 30 tons to 40 tons daily capacity, is 18 ft. and the width of the grate 3 ft.

Features.—(1) The machine is very compact for the amount of effective grate area, occupying small floor space and requiring little head room.

(2) The separate suction for the igniter insures a much stronger draught at the point of ignition, and consequently the top layer is thoroughly sintered.

(3) By use of the compartment grate all hand breaking of the sinter is eliminated.

(4) The grate going around the sprocket and thus changing curvature at the point of discharge, breaks away from the sinter and obviates the barring and wedging necessary when a grate of constant curvature is used.

The machine can be used with the regular up-draught by making the suction box (6) a wind box; the suction fan a blower; reversing the position of the igniter, placing it under the grate end and priming through it. In this case a hood should cover the grate.

The cost of sintering with this machine would be far lower than with pots. The mechanical arrangement of a plant operating with these can be so adjusted as to make labor a minimum. The ore and flue dust, or whatever mixture is used, can be thoroughly mixed in a concrete mixer, or a similar appliance, and taken directly to the feed hopper for the machine, where the firing of the igniters and the regulating of the charges for a battery of several machines can be attended to by one man. The dumping is automatic and the sinter could drop directly into small bins just above the charging floor level of the blast furnaces—that is, should the topography of a smelter site allow such an arrangement. At any rate, the labor required would be a minimum. With the exception of the Bormette process, the use of which is not extensive, any of the ordinary sintering methods can employ this machine, and with its reduced cost of operation, I think it will go quite a way in making sintering an economic success.

The Attainment of Highest Purity Iron on a Commercial Basis.

By James A. Aupperle.

The United States Patent Office recently granted to R. B. Carnahan, Jr., two patents,* No. 940,874 and 940,875, covering the process and product for the manufacture of iron of exceptional purity. This iron is known in the trade as American ingot iron and is manufactured by the American Rolling Mill Company of Middletown, Ohio. It possesses properties so radically different from steel, that a description of the process and product will be of interest.

The process of manufacturing American ingot iron consists of charging a high-powered basic open-hearth furnace with iron and high-grade scrap, employing therewith agents for the elimination of the carbon, manganese, silicon, sulphur, and phosphorus, refining the charge in a molten condition at such a high and increasing temperature, and for such a prolonged period, that analysis of bath test shows that the sulphur, phosphorus, carbon, manganese, and silicon, are not over 0.14 when taken in the aggregate, pouring the hot purified iron into moulds, and while in a molten condition, deoxidizing and degasifying to such an extent that the product will not contain over 0.05 oxygen as determined by the method of Ledebur, but will contain at least 99.80% iron.

In practice it is possible to eliminate the silicon, sulphur, phosphorus, carbon, and manganese to 0.03 when taken in the aggregate. The manufacture of American ingot iron is a process of elimination from start to finish, one of the eliminating agents being oxygen.

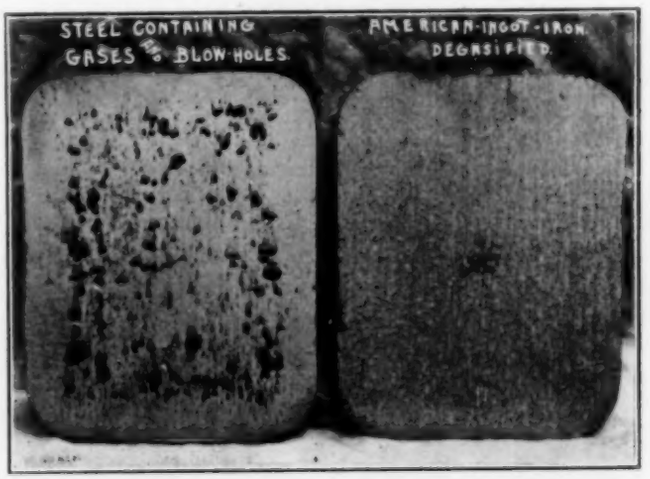


FIG. 1.—COMPARATIVE TRANSVERSE SECTIONS OF INGOTS.

The process is based on the assumption that iron will not dissolve more than 0.30 oxygen. It is thus a very flexible process, as a large excess of iron ore or mill scale can be added to the bath for the purpose of eliminating the impuri-

*See pages 62 and 98 of the February issue of this journal.

ties, and at the same time the bath at the end of melt will not contain more than 0.30 oxygen, which is then partly deoxidized in the furnace with pig iron, or ferro-silicon.

The deoxidation and degasification are completed in the ladle with aluminium, so that the finished iron will contain less than 0.05 per cent. oxygen and more often the oxygen content will be nearer 0.01 per cent.

Fig. 1 shows a transverse section sawed from the middle of ingots on which no rolling or hammering was done. It shows how completely American ingot iron (at the right) is degasified and also shows the large number of blow holes in the steel (at the left). These ingots were of the following analysis:

	American Ingot Iron.	Steel.
Carbon	.010	.10
Manganese	.003	.35
Silicon	.002	.012
Sulphur	.015	.031
Phosphorus	.001	.065
Oxygen	.012	.034
Specific Gravity	7.95	7.72

It will be seen that the specific gravity is considerably higher in American ingot iron than steel, and often exceeds 8.00 in the rolled sections.

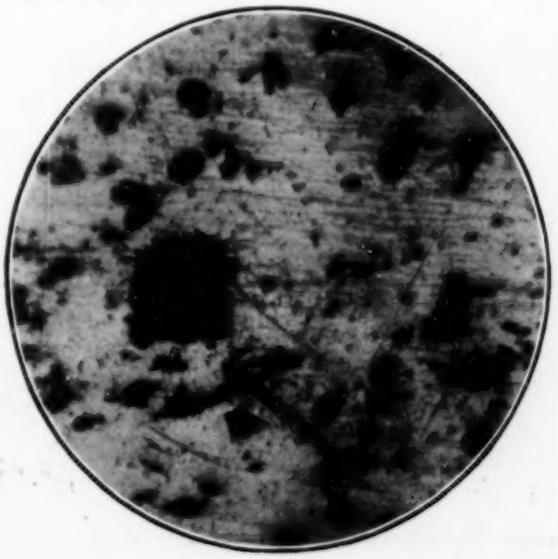


FIG. 2.—TRANSVERSE SECTION. WROUGHT IRON. 56 DIA. SLAG SPOTS. NOT ETCHED.

The importance of low oxygen content of American ingot iron was early recognized, as it was found that besides making the iron red short, it would not galvanize economically if the oxygen exceeded 0.05. The excess of oxygen also caused rapid corrosion. A sample containing above 0.05 oxygen will dissolve more rapidly in acid than material containing below 0.03 oxygen, which is undoubtedly due to the electro-negative character of oxygen, it being more electro-negative than any other element, with the possible exception of fluorine.

The remarkable resistance of American ingot iron to corrosion is shown by the fact that in a 25 per cent. solution of sulphuric acid at 70° C. some grades of 16-gauge Bessemer sheet steel will dissolve in 30 minutes, while under the same conditions, American ingot iron will lose 1/3 of 1 per cent, or in the ratio of 1 to 300.

However, in open-hearth steel of low oxygen contents, the loss is much less than in Bessemer steel, but the American ingot iron is at least twenty times as resistant to sulphuric acid attack as the best open-hearth steel.

Another instance is shown by a neutral copper-sulphate test, where the American ingot iron is several times better than open-hearth steel. This fact is interesting, as it makes the metal suitable for use where there is water containing copper in solution.

In fused caustic soda it outlasts steel about two to one. American ingot iron enamels far better and can be more easily drawn than steel, and also alloys better with cast iron, so that molten cast iron can be poured around it and a perfect union takes place.

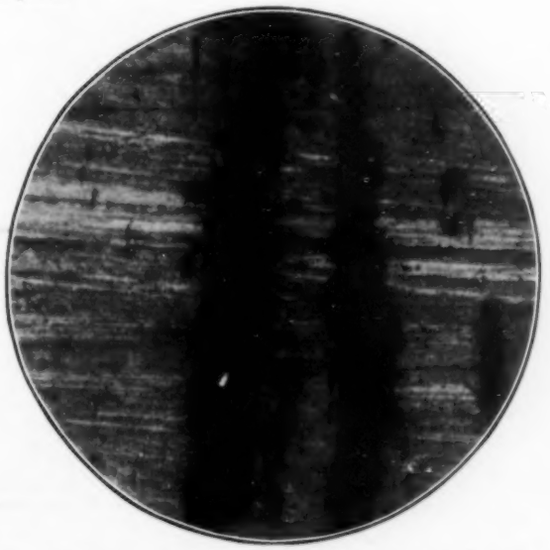


FIG. 3.—LONGITUDINAL SECTION. WROUGHT IRON. 56 DIA. SLAG LINES. NOT ETCHED.

The following table shows the physical properties of American ingot iron to be superior in every respect to wrought iron.

Material	Elastic Limit	Ultimate Stress	Per Cent. Elongation 8 in.	Red. of Area
American Ingot Iron (unannealed)	32290	55550	22.4	54.0
Wrought Iron	30400	49050	16.0	22.4

From the fact that American ingot iron is made in an open-hearth furnace, there is a tendency to call the material steel, but

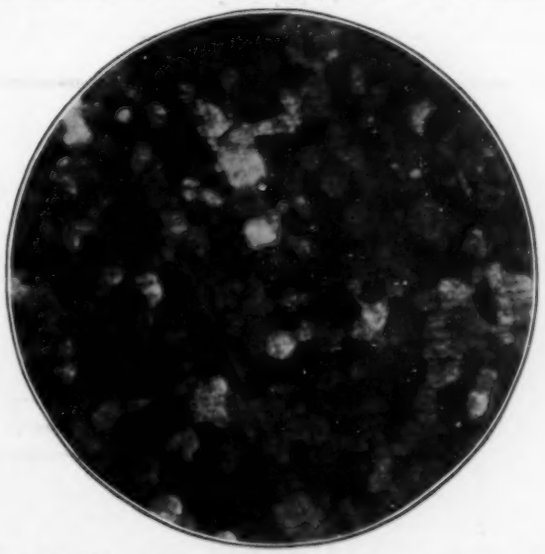


FIG. 4.—AMERICAN INGOT IRON. 56 DIA. DEEPLY ETCHED. GRAINS OF FERRITE.

steel being a compound and American ingot iron practically an element, there is no good reason for calling it steel, and when examined under the microscope, the structure seen is ferrite, which according to the present nomenclature is nearly pure iron. About the same amount of pearlite is present as in the

best Swedish iron (traces only). The micro-structure of American ingot iron and Swedish iron is identical as to the ferrite constituent, the only difference being a few scattered slag lines in the longitudinal and slag dots in the transverse sections of Swedish iron.

In a microscopical examination of a longitudinal section of the common grade of wrought iron (Fig. 3) the large slag lines show a marked difference between it and American ingot iron, which contains no slag.

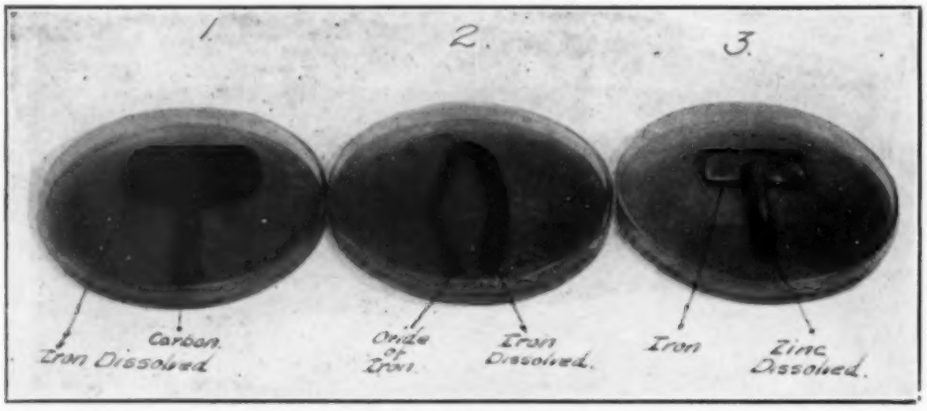


FIG. 5.—ELECTROLYTIC CORROSION TESTS.

Fig. 5 shows the effect of positive and negative elements in contact with American ingot iron.* Dish No. 1 shows the effect of carbon in contact with American ingot iron, the carbon being electro-negative, the hydroxyl ions cluster about it and are indicated by the phenolphthaline producing a red color. The positive iron dissolves and is indicated by the blue color produced with potassium ferri-cyanide. American ingot iron contains but traces of carbon, consequently there is less electrolytic action than in steel, which often contains a considerable amount of carbon.

Dish No. 2 shows the effect of oxide of iron in which is a piece of wire, one-half containing oxide of iron, the other half free from oxide, and thus shows the electro-negative character of the oxide of iron, the narrow half of the wire being the oxidized side; the wider half shows where the iron has gone into solution, forming Turnbull's blue, while the side containing the oxide of iron became red from the presence of hydroxyl ions.

American ingot iron being exceptionally low in oxide of iron, there will be less electrolytic action than in steel containing considerable oxide of iron.

In Dish No. 3 the electro-positive nature of zinc is plainly indicated, in which a piece of zinc is placed in contact with a strip of American ingot iron, in this case the hydroxyle ions cluster around the iron producing a red color, the zinc in this instance dissolving as zinc hydroxyle and thus protects the electro-negative iron.

This would indicate that should the spelter become broken on American ingot iron there would be very little iron corroded, until the zinc has all disappeared and thus indicates the excellent protection that zinc imparts to iron.

Fig. 6 shows how much better American ingot iron alloys with zinc than steel and also the better protection afforded in resisting the corrosive action of sal ammoniac flux. Two collars, one ingot iron, the other steel, each 4¼ in. diameter were put on the necks of the exit rolls of a galvanizing machine, one-half of the roll was immersed in molten spelter, the other half surrounded by sal ammoniac flux. The steel collar corroded five times as fast as the collar made from American ingot iron.

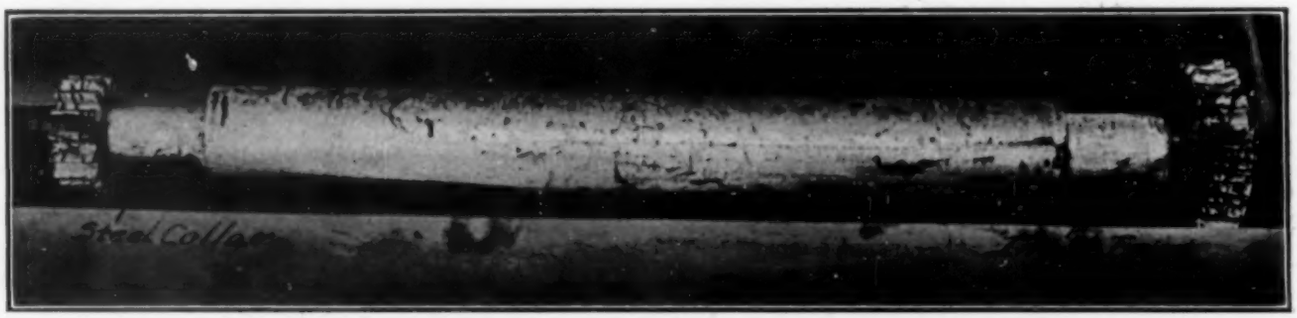


FIG. 6.—STEEL COLLAR AND INGOT IRON COLLAR.

Professor Charles F. Burgess of the University of Wisconsin, has the following to say about American ingot iron:

"From time to time we have made microscopic examinations of American ingot iron and have found its structure to indicate high purity, homogeneity, and absence of slag. And from the microscopic appearance we have every reason to believe this iron to be equal to the best Swedish iron in its physical properties and to have the advantage over Swedish iron due to the absence of imperfections caused by slag.

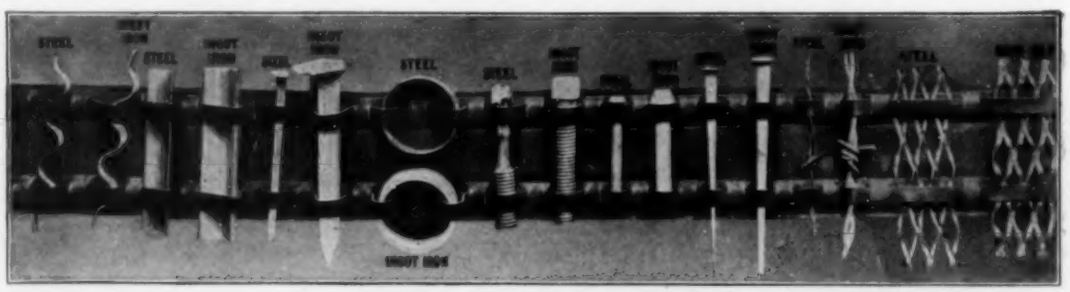


FIG. 7.—INGOT IRON AND STEEL CORROSION TESTS.

"We have used a large amount of this material for the

*Concerning the electrolytic theory of corrosion and methods of making the anode and cathode spots visible by different colors, see especially the papers of Cushman and Walker, for instance, Vol. V of this journal, page 363 and 365 (1907).

anode in our electrolytic refining tanks and the manner in which it corrodes shows that it is more dense and uniform than most of the other soft irons we have tried. It is comparatively free from fibers which are so pronounced in some grades of soft iron, which we have employed. In our magnetic tests also, the ingot iron seems to be strictly comparable to high-grade wrought iron.

"As regards corrosion, our experience has been that on ac, count of the absence of impurities, and the uniformity of its structure, there is less local electrolytic action than in most other grades of iron. The result of this is that it dissolves less rapidly than will most other forms of iron."

Prof. J. W. Langley, of Ann Arbor, Mich., refers to American ingot iron as follows:

"American ingot iron is extraordinarily tough and ductile, ranging above wrought iron, and closely approximating the best grade of mild steel of .10 carbon.

"Its combination of great ductility with a fair degree of tenacity is remarkable, and when considered in connection with the resistance to corrosion, makes a distinctly new metal of it. In resistance to acids such as diluted sulphuric and hydrochloric, it resists on an average about twenty times the corrosion of open-hearth steel."

MIDDLETOWN, OHIO.

The Chemist in the Brass Foundry.*

BY W. M. CORSE.

The statement has recently been made that the twentieth century is going to be the era of the chemical engineer, as the nineteenth was of the mechanical engineer. One has but to look about him to see evidences of this development to realize the truth of this statement. More and more of our manufacturers are coming to see that the underlying principles of their processes are chemical and that a knowledge of these principles is essential to the proper conduct of their business if it is to be run at a profit. The brass manufacturer has begun to see this condition, and the number of testing laboratories that have been installed in connection with this industry are proof of this fact.

I have had the good fortune to install four chemical laboratories, three of which have been in connection with brass foundries. A short history of their development may be of interest. The first came into being because of the trouble the manufacturer had with metal melted in oil furnaces. The furnaces did not use a crucible, and the flame came into direct contact with the metal. Oxidation of the metal was greater than in the old-style crucible coke furnace, and the composition of the mixture was varied to such an extent that very bad results were obtained from the castings when they were subjected to hydraulic pressure.

My first work was to ascertain the amount of oxidation and volatilization in order to maintain the composition of the resulting alloy uniform. Numerous tests were made and it was found that 35 per cent more zinc was lost than was allowed for. It was also found that all the remelt was put into one general pile and as this amounted to 50 per cent of the melt, the indiscriminate use of this remelt changed the formula very materially. One thing led to another, until finally all formulas for metal were made up in the laboratory and the resulting melts were analyzed regularly to see if these formulas gave the desired result.

This all may seem very simple, and undoubtedly is, but the fact is that the majority of brass founders are in ignorance of just these principles of their daily operation. The last seven years have witnessed remarkable strides along such lines as described, so that some foundries now know considerably more than they did before the chemist was employed.

Many times I have been asked the question, "Of what use is a chemist in a brass foundry?" This question was asked by men actually operating foundries. To-day the number of analyses made is probably 500 times as many as five years ago. Although the manufacturer may not have come to the point of using the chemist, he is generally willing to concede his value.

From testing the furnace products for formula, I worked to examine the raw materials for purity. These include copper, tin, lead, zinc, ingot brass, scrap brass, and sometimes antimony. Aluminium also comes in prominently for some kinds of work and has to be tested. The majority of aluminium casting makers buy their alloys ready made as it were, so that less work is done on their component parts than on finished alloys.

The cost of an alloy is, of course, determined by the cost of its component parts, and when these vary quite widely in price, a variation in composition sometimes means the difference between profit and loss. For instance, copper costs now about 14 cents per pound and zinc and lead average 5 cents per pound. An alloy figured for 70 per cent copper, but actually carrying 72 per cent will cost 18 cents a hundred pounds more than it should cost. On a weekly melt of 100,000 lb. this means $180 a week, or $9,360 a year.

This is by no means an unusual instance, and goes to show what a very small saving per pound may mean. It also shows how the exact control of a formula may save money for the manufacturer. It is safe to assert that over a thousand pairs of metals have never been alloyed, and many times this number of combinations of three or more metals have never even been thought of. The surface of this enormous field has scarcely been scratched and offers as much promise for investigation as any that I know.

If any industry needs the attention of the technical man it is the foundry business. Rule-of-thumb methods predominate and opportunities for investigation lie at every hand.

In addition to the metallurgy, we have the various refractory materials and their connection with furnace design and upkeep. They comprise such things as fire brick, fire clay, fire sand and carborundum. The various molding sands come in for attention too. These should be tested for fineness, binding qualities, resistance to hot metal, porosity, etc. Core sands are tested for fineness and refractory qualities. Crucibles are an important item of expense and should be tested regularly to insure maintaining uniform quality.

Coke can be tested for ash and sulphur although a practical test for burning qualities is generally the most important. If oil is used for fuel, it also comes into the laboratory for test.

All brass foundries have copper-bearing refuse of various kinds, which cannot be worked up satisfactorily with the equipment generally available. In order to sell these for anything like their proper value, it is necessary to know either their metallic content or their copper content, which again makes work for the chemist.

As a general thing experimental work cannot be properly taken care of by the foreman. The nature of his duties prevents him from giving concentrated attention to any problem for any great length of time, inasmuch as continued interruptions render impossible the proper recording of his observations. The chemist is, therefore, the logical man to conduct this kind of work. It usually happens that the chemist is the only technical man around the foundry, so that it properly falls to his lot to record the results of all tests made, whether they are chemical, physical, or practical tests of material. He often can be of help in devising production records, loss reports and summaries of such things as pounds produced per man per day, fuel consumed per 100 lb. of metal melted and others too numerous to mention. He can do the planning for engineering work such as is commonly required in a foundry and can aid in the solving of such engineering problems as may arise.

I think I have made it sufficiently clear how a chemist can be used to advantage in any brass foundry large enough to warrant

* Presented at the March meeting of the Chicago section of The American Chemical Society.

the outlay for a laboratory. For smaller foundries the commercial testing laboratory is available and does very satisfactory work along some lines. Experience has shown me that many foundries would employ their own metallurgist, as the brass foundry chemist may properly be called, did they but realize the many uses to which his services could be put.

In my position as Secretary of the American Brass Founders' Association, I have had exceptional opportunities to watch the development of the brass foundry laboratory and I have observed that the manufacturers who are making the highest quality goods in a business-like manner are foremost in utilizing this department. Could the practical foundryman be made to realize that a technical man makes his own position more valuable and co-operation vastly increases his own usefulness, a great step forward would be taken in this ancient and intensely interesting industry.

Concentration of Sulphuric Acid.

In our February issue, page 97, we gave an account of the first part of an article by Dr. Gustave Lüttgen in the *Chemiker Zeitung* of January 11, on concentration of sulphuric acid.

The reason for this article is the fact that the hopes placed in the contact process for making sulphuric acid have not been fulfilled in the experience of the last few years, that the numerous difficulties have not been overcome, and that the process is very sensitive. Moreover, the chamber process has had marked improvements in design and operation, and as a result the necessity has arisen for presenting the latest improvements in apparatus for concentration of chamber acid.

The author discusses first the "dish system" (cascade), with its breakage, loss of acid and high fuel consumption; second, the tower system, with its difficulty of operation, expense of installation, high fuel cost and large production of weak acid;* and, third, the "pan system," perhaps better described as "entrainment system" Kessler).

Dr. Lüttgen's article goes on to say that the old Kessler apparatus is so well known that its detailed description is unnecessary. As there is, however, little general knowledge regarding the recent improvements in the Kessler apparatus, the most commanding points will be described.

In the old Kessler system the "saturex" consists of a rectangular chamber built of "volvic" lava having longitudinal channels of pumice stone. The hot gases passed into the "saturex" through channels open at the bottom and reaching downward to the surface of the acid contained in the saturex.

The principle itself was excellent, but the pumice stone was subject to disintegration and failed after a certain time. As a result the gases of combustion did not pass sufficiently through the acid before going to the recuperator, so that the output was decreased. Also these channels did not permit easy cleaning of the saturex because the pumice stone would not stand rough usage.

The Kessler works, owned by Mr. J. Teisset, have now remedied this by the following arrangements, patented by Teisset-Prat in 1909. Instead of the longitudinal pumice stone channels, transverse dividing curtains of volvic lava are now used. The saturex is thus divided into cells above, against which the acid waves caused by the counter flow of hot gases strike.

These changes have increased the output, and also made cleaning very easy, since dividing walls may be taken out for inspection and put back in place without any difficulty. There is practically no breakage and no accumulation of acid mud. The acid produced is always concentrated and perfectly clear.

In the old Kessler apparatus the hot gases were drawn through by one or two steam ejectors of special construction. The porcelain nozzle had to be adjusted very exactly to the steam pressure, and was a rather delicate piece of apparatus. Furthermore, steam pressure was subject to change, whereby the output was diminished. To overcome these disadvantages the steam jet has been replaced by a special apparatus at the end of the system. (Teisset-Prat patent, 1909.)

Some manufacturers tried to insert an exhauster of hard lead or soft lead between the apparatus and the filter. But in these cases it was found that the output decreased, and it was necessary several times in a month to take out the impellers for the sake of repairs necessitated by the attack of the hot acid vapors. There is no danger of this kind with the new apparatus, by which the air is forced from the outside into a pressure transformer inserted in the gas pipe coming from the coke boxes. In the pressure transformer the pressure is reduced, and this reduced pressure is communicated throughout the apparatus.

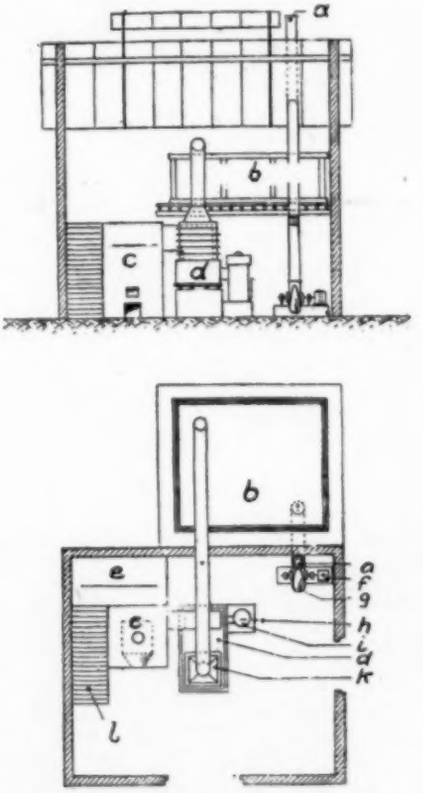


FIG. I.—CONCENTRATION OF SULPHURIC ACID.

a, steam escape; *b*, condenser; *c*, gas producer; *d*, saturex; *e*, platform; *f*, electric motor; *g*, ventilator; *h*, acid exit; *i*, cooler; *k*, recuperator; *l*, stairway.

With this arrangement the acid vapors do not get into the pressure reducer, so that its life is practically unlimited. Further, while the steam escaping into the air was slightly acid with the old Kessler apparatus, it contains no acid whatever in the new apparatus. On account of these important improvements, the cost of concentration has been considerably reduced.

In the new Kessler apparatus from 80 to 100 kilograms of coke are required per ton of sulphuric acid of 92-93 per cent. The power required is 0.6 horsepower hour per ton. The quantity of weak acid is less than with the old Kessler apparatus, about 80 kilograms of 36° Beaume per ton.

Further, first chamber acid may be used, as the apparatus is very easily cleaned. With the old apparatus of 10-ton capacity two coke boxes were necessary, while one of them may be omitted with the new apparatus. The temperature of the gases when leaving the last plate is only 90°C.

The cost of installation in Germany of the improved Kessler apparatus with a capacity of 10 tons of sulphuric acid of 92-93 per cent is about $6,000, while the cost of repairs has been greatly reduced by the improvements.

* Concerning these two processes see our February issue, p. 97.

Steam is no longer required for the operation of the apparatus. Since electric power is now available everywhere, the new concentration may be placed wherever it is most convenient.

Finally, the new apparatus has also solved the important problem of concentrating chamber acid to acid 98 per cent at small cost. The ease of concentration is largely due to the improvements noted above, as well as the high thermal efficiency.

Radiation losses are reduced to a minimum by the compact construction of the apparatus. This results in a high thermal efficiency.

The coke consumption for concentration to 98 or 99 per cent is from 180 to 190 kilograms per ton; the energy required is 1.5 hp-hours per ton.

An apparatus which yields 10,000 kilograms of 93 per cent

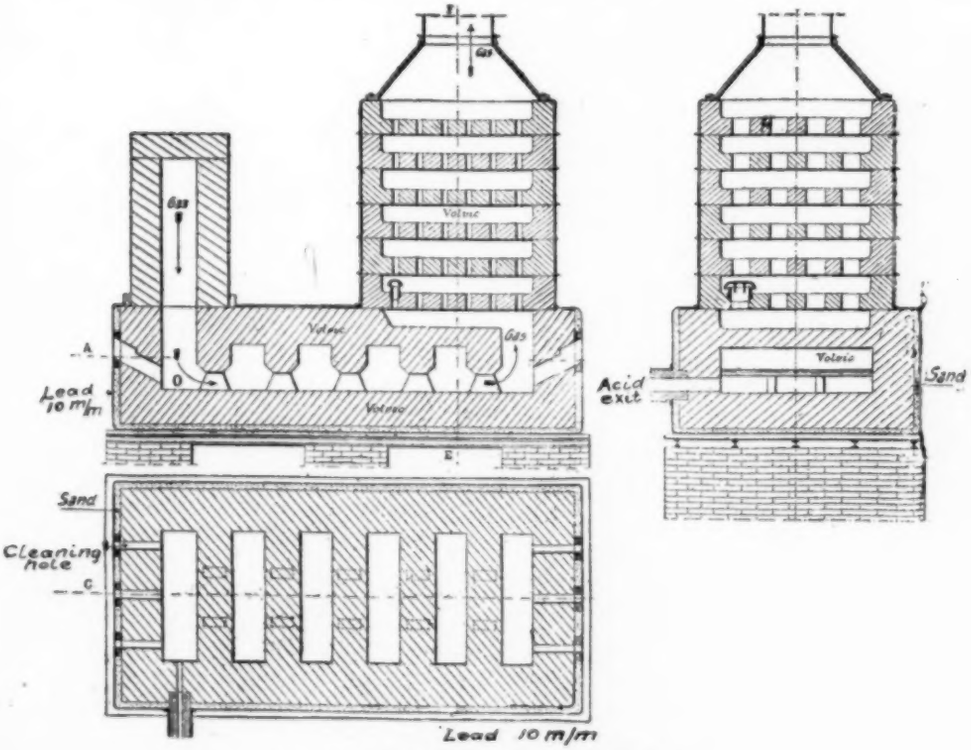


FIG. 2.—CONCENTRATION OF SULPHURIC ACID.

H_2SO_4 yields about 5000 kilograms of 98-99 per cent H_2SO_4. With this concentration the quantity of weak acid is less than 25 per cent.

The following table is a comparative summary of the results obtained with the various concentration apparatus described for a production of 10,000 kilograms of 92-93 per cent H_2SO_4 in 24 hours:

DAILY PRODUCTION, 22,000 LBS., 92-93 PER CENT H_2SO_4, 98-99½ H_2SO_4

	Cascade.	Tower.	Kessler.	Improved.	Improved Kessler.
Coke consumed, lbs.	3,300	2,420 to 2,640	2,200 to 2,420	1,760 to 2,200	1,980 to 2,090
Power used, hp.	2½ to 3	7 to 8	20*	6 to 7	7½
Weak acid, lbs.	1,320	4,620 / 1,100	2,640	1,760	2,200 ....
Weak acid, deg.	15	40 / 14	25 ..	36 ..	38 ..
Installation, cost in dollars	5,000	10,000 to 12,000	6,000 to 7,000	5,600 to 6,000	....
Height without coke filter, in ft.	12	21 to 45	10½	10½	..

* Coal equivalent to 20 hp.

The Chemical Industries of America*

By Prof. Charles E. Monroe.

(*Concluded from page* 196.)

Having confessed myself, and having found my profession guilty, as charged, I now assert that a chief duty of our profession is to determine methods by which the income may be increased or the costs of living in the land decreased, or preferably both, and I urge as a first measure the advocacy of the policy of preventing any material from leaving the country until it has passed through all processes of manufactures of which it is capable. The meaning of this is evident on inspecspection of the exports of domestic merchandise prepared by the United States Bureau of Statistics, where we find that in 1908 over $885,000,000 worth, or 48.19 per cent of the total exports, consisted of cotton, breadstuffs, meat and dairy products, and coal, much of which had not undergone any degree of manufacture whatever. All this food should have been elaborated in this country into brain and brawn, and the coal made to yield its energy, and then should have been expended here in manufacture. We should further have put into manufacfactured form the raw materials of other lands.

Inspecting, on the other hand, the table of imports of merchandise prepared by the United States Bureau of Statistics we find that in 1908 but a little over $210,000,000 worth, or 17.87 per cent, of our imports consisted specifically of unmanufactured materials, such as silk, hides and skins, india rubber and gutta percha, wool, cotton, copper, lead and iron ores, and bristles, which would properly go into manufactures here.

We sit back glorying in our country. Its wide extent. Its rich resources. Its teeming millions of independent and self-respecting people. And yet after our fleet has circumnavigated the globe, we continue to sacrifice the fertility of our soils to the support of older civilizations and remain content, while ranging ourselves with those nations that live solely on their primary resources, since the "balance of trade" is in our favor. But we, as chemists, know that this condition cannot last. We know that the average fertility of our soil has been growing steadily less and that only by following sound scientific practice can the fertility of the impoverished soil be restored.

The utilization of the soil as a chemical factory is but one of the problems with which the chemist has to deal. That which appeals most nearly to us as chemical engineers is the item that appears as second in magnitude in the Table of Imports of Merchandise and which has held this second place for years, namely, "Chemicals, drugs and dyes," for this category embraces those substances commonly knowns as chemicals, or the products of the "black art." In 1908 we imported $73,237,033 worth of this class of materials, or 6.13 per cent of our total im-

*Address delivered, by invitation, on December 9, 1909, at the annual meeting of the American Institute of Chemical Engineers in Philadelphia.

ports, while we exported but $20,873,155 worth, or 1.14 per cent of our total exports. There was, therefore, a balance of $52,363,878 against us in this item, in which the chemical engineers of this country are most nearly concerned.

It is true that among these imports are upward of $15,000,000 worth of crude drugs and dyewoods, and quantities of other crude material, but there are many million dollars' worth of substances included here that should have been manufactured in this country. Attention need only to be called to the acids imported to a value of over $1,300,000 to emphasize this fact, for while we are seeking an outlet for our sawdust, we find in this list nearly 9,000,000 lb. of oxalic acid. Or attention might be called to the more than $7,000,000 worth of coal-tar products and preparations, not medicinal. Had this been accomplished there is little doubt that our exports of such substances would also have been large. And what is true of the industries commonly called chemical would equally apply to those larger chemical industries not included in the common category.

Another policy we should follow is the promotion of chemical manufactures throughout a larger portion of our great territory. For this purpose I have prepared Table VI, showing by States the locations of each of the 1786 establishments reported for chemicals and allied products at the census of 1905.

And I find that seven States or Territories, viz., Arkansas, Idaho, Montana, New Mexico, North Dakota, South Dakota and Utah, did not at that time possess a single establishment devoted to any of the large number of industries embraced in chemicals and allied products. Oklahoma, New Hampshire and Wyoming each possessed but one, and the District of Columbia, Nebraska, Nevada, Oregon, Texas and Vermont each less than five.

In order to bring this matter of the distribution of the industries manufacturing chemicals and allied products more clearly to your attention I have, through the courtesy of the director

TABLE VI—NUMBER OF ACTIVE ESTABLISHMENTS FOR CHEMICALS AND ALLIED PRODUCTS, BY STATES, 1905

	1905		1905
Alabama	27	Mississippi	7
Alaska	1	Missouri	47
Arizona	..	Nebraska	4
California	63	Nevada	3
Colorado	6	New Hampshire	1
Connecticut	40	New Jersey	144
Delaware	13	New York	204
District of Columbia	3	North Carolina	42
Florida	15	Ohio	128
Georgia	75	Oregon	4
Illinois	89	Pennsylvania	315
Indiana	52	Rhode Island	17
Indian Territory	1	South Carolina	26
Iowa	6	Tennessee	22
Kansas	10	Texas	3
Kentucky	21	Vermont	3
Louisiana	12	Virginia	62
Maine	9	Washington	9
Maryland	59	West Virginia	25
Massachusetts	77	Wisconsin	19
Michigan	52	Wyoming	1
Minnesota	10		

TABLE IV—VALUES OF EXPORTS OF DOMESTIC MERCHANDISE, BY PRINCIPAL ARTICLES AND CLASSES, IN ORDER OF MAGNITUDE IN 1908, DURING THE YEARS ENDING JUNE 30, 1902–1908

Order of Magnitude, 1908	Articles	1902	1903	1904	1905	1906	1907	1908	
								Value	Per Ct. of Total
		Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	
1	Cotton, unmanufactured	290,651,819	316,180,429	370,811,346	379,965,014	401,005,921	481,277,797	437,788,202	23.86
2	Breadstuffs	213,134,344	221,242,285	149,050,378	107,732,910	186,468,901	184,120,702	215,260,588	11.73
3	Meat and dairy products	199,861,378	179,839,714	176,027,585	169,998,873	210,990,065	202,392,508	192,802,708	10.51
4	Iron and steel, and manufactures of	98,552,562	96,642,467	111,948,586	134,728,363	160,984,985	181,530,871	183,982,182	10.03
5	Copper, and manufactures of	43,820,070	40,594,613	58,119,006	87,564,009	83,178,635	96,600,698	105,872,711	5.77
6	Mineral oils	72,302,822	67,253,533	79,060,469	79,793,222	84,041,327	84,855,715	104,116,440	5.67
7	Wood, and manufactures of	47,779,848	57,743,535	65,428,417	58,002,977	69,080,394	83,349,575	81,521,305	4.44
8	Leather, and manufactures of	29,798,323	31,617,389	33,980,615	37,936,745	40,642,858	45,476,969	40,688,619	2.22
9	Tobacco, and manufactures of	32,772,849	40,444,689	34,683,531	35,491,019	34,218,847	39,113,011	39,463,679	2.15
10	Coal	20,765,461	21,206,498	27,820,323	29,158,322	28,216,376	34,727,762	39,355,759	2.15
11	Animals	44,871,684	34,781,193	47,977,875	46,728,281	49,139,568	41,203,080	34,101,289	1.86
12	Cotton, manufactures of	32,108,362	32,216,304	22,403,713	49,666,080	52,944,033	32,305,412	25,177,758	1.37
13	Agricultural implements	16,286,740	21,006,622	22,749,635	20,721,741	24,554,427	26,936,456	24,344,398	1.33
14	Cars, carriages, etc	9,872,516	10,499,195	10,936,618	10,610,437	17,788,425	20,513,407	22,072,902	1.20
15	Naval stores	11,733,562	12,918,708	16,145,222	16,106,643	20,075,585	21,686,752	21,641,599	1.18
16	Oil cake and oil-cake meal*	19,779,142	19,743,711	16,899,257	21,498,085	23,386,218	25,738,471	21,064,974	1.15
17	Chemicals, drugs, dyes and medicines	13,626,837	14,150,493	15,065,682	16,595,523	19,155,989	20,373,036	20,873,155	1.14
18	Vegetable oil	15,308,633	16,234,362	12,618,381	16,633,232	15,906,031	19,550,514	19,033,967	1.07
19	Fruits and nuts	8,719,344	18,057,677	20,678,665	15,606,586	15,274,158	17,588,432	14,338,864	.78
20	Instruments for scientific purposes	5,389,476	7,130,508	8,297,723	8,172,980	10,887,774	13,661,455	11,578,010	.63
21	Fertilizers	6,256,035	6,724,301	7,112,512	7,620,886	8,686,965	8,596,711	10,970,931	.59
22	Paraffin and paraffin wax	8,858,844	9,411,294	8,859,964	7,789,160	8,808,245	9,030,992	8,740,929	.48
23	Seeds	8,027,824	9,455,283	2,583,325	2,557,747	8,912,602	10,094,609	8,683,688	.47
24	Paper, and manufactures of	7,312,030	7,180,014	7,543,728	8,238,088	9,536,065	9,856,733	8,064,706	.44
25	Furs and fur skins	5,030,204	6,181,115	5,422,945	6,599,222	8,002,282	7,139,221	7,712,890	.42
26	India rubber, manufactures of	4,032,100	4,675,157	5,148,959	5,508,664	6,343,735	7,428,714	7,573,570	.41
27	Fibers, vegetable, etc., manufactures of	4,575,219	5,290,948	6,414,636	6,766,809	8,157,211	8,308,112	7,225,798	.39
28	Books, maps, engravings, etc	3,997,977	4,442,653	4,347,304	4,844,160	5,839,452	5,813,107	6,107,053	.33
29	Grease, grease scraps, etc	3,610,925	2,926,565	3,311,777	3,710,907	4,138,333	5,473,623	5,762,709	.31
30	Fish	6,563,199	6,717,274	7,857,041	6,527,863	7,559,178	5,536,856	5,685,916	.31
31	Household and personal effects	2,570,369	2,652,787	2,615,076	3,146,969	3,595,128	3,928,946	4,782,436	.26
32	Coffee, green	3,209,946	3,295,968	3,656,943	1,966,107	3,483,238	4,692,137	4,314,020	.24
33	Sugar, molasses, and confectionery	3,237,329	3,104,653	3,522,805	4,131,707	4,526,334	3,973,360	4,068,357	.22
34	Paints, pigments, and colors	2,096,379	2,350,937	2,756,581	3,126,317	3,773,064	3,931,899	4,001,824	.22
35	Vegetables	2,546,287	2,543,488	2,603,374	3,200,860	3,567,127	4,007,833	3,895,294	.21
36	Explosives	2,062,381	2,454,510	2,441,596	2,559,837	3,568,038	4,082,402	3,705,517	.20
37	Brass, and manufactures of	1,930,810	2,000,432	2,557,484	3,025,764	3,474,981	4,580,455	3,701,871	.20
38	Soap	1,630,938	2,452,777	2,499,933	2,670,231	2,781,179	3,806,097	3,407,220	.19
39	Musical instruments	3,694,143	3,381,509	3,230,982	3,144,787	3,168,052	3,256,063	3,371,521	.18
40	Hops	1,550,657	1,909,951	2,116,180	4,480,666	3,125,843	3,531,772	2,963,167	.16
41	Nickel, nickel oxide, and matte	1,190,606	864,221	940,558	3,190,622	3,240,544	3,218,862	2,948,058	.16
42	Clocks and watches, and parts of	2,144,490	2,133,539	2,281,195	2,316,414	2,598,441	3,169,272	2,848,725	.16
43	Coke	1,720,457	1,912,459	2,223,233	2,228,442	2,435,604	3,013,088	2,718,385	.15
44	Glucose and grape sugar	2,319,286	2,460,022	2,949,545	3,206,794	3,489,192	3,017,527	2,540,640	.14
45	Glass and glassware	1,960,106	2,150,699	1,978,481	2,252,799	2,433,904	2,604,717	2,505,417	.14
46	Wool, manufactures of	1,512,457	1,722,128	1,987,938	2,035,054	2,119,518	2,239,106	2,219,815	.12
47	Lamps, chandeliers, etc	963,638	1,133,390	1,502,888	1,579,125	1,954,091	1,875,869	1,827,216	.10
48	Spirits, distilled	2,673,273	1,990,091	1,691,467	1,968,767	1,525,225	1,827,757	1,816,287	.10
49	Zinc, and manufactures of	2,017,191	2,346,629	1,710,211	3,085,243	2,780,199	2,143,574	1,606,032	.09
50	Hay	2,580,622	828,485	1,052,705	1,089,505	1,116,307	976,287	1,463,010	.08
51	Marble, stone, and manufactures of	1,761,696	1,465,244	1,589,790	1,283,219	1,466,561	1,433,123	1,248,996	.07
52	Starch	656,705	832,943	1,340,282	1,430,572	1,490,797	1,126,465	1,142,054	.06
53	Malt liquors	1,290,062	1,178,740	854,119	1,012,808	1,116,776	1,215,340	1,020,172	.06
	All other articles	23,761,904	22,557,283	25,770,532	30,732,482	30,998,594	35,784,782	38,463,024	2.10
	Total	1,355,481,861	1,392,231,302	1,435,179,017	1,491,744,641	1,717,953,382	1,853,718,034	1,834,786,357	100.00

*Corn oil cake not included.

of the Bureau of the Census, had prepared a map* of the United States showing the location of the establishments, both principal and subsidiary, manufacturing sulphuric acid, those making explosives, and those engaged in wood distillation, each being a typical industry, and the sulphuric acid industry being generally accepted as of fundamental importance.

From this chart it appears that 13 States and Territories, being the seven already named (Arkansas, Idaho, Montana, New Mexico, North Dakota, South Dakota, Utah) with Iowa, Nebraska, New Hampshire, Nevada, Oregon, and Wyoming, containing 7,648,000 out of the 76,303,387 inhabitants of the continental United States in 1905, or over 10 per cent of the whole, did not possess a single establishment devoted to any one of these industries.

Considering sulphuric acid only, which is so important an industry that it has frequently been referred to as an index of the state of civilization of a people, we find that 23 States and Territories, namely, the 13 just enumerated, together with Delaware, District of Columbia, Kentucky, Maine, Minnesota, Missouri, Oklahoma, Washington and West Virginia, containing 19,562,200 population, or 25.6 per cent of the total, did not possess a single sulphuric acid plant within their borders.

*This map will be printed in a later issue.—ED.

Turning now to the East, we find that 11 out of the 13 original colonies, viz: Connecticut, Georgia, Maryland, Massachusetts, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, South Carolina and Virginia, contained 30,695,000 population, or 40.2 per cent of the total, and 100 sulphuric acid factories, or 67.1 per cent of the total number existing in the country. Analysis of the statistics of the separate States shows that the number of these establishments does not follow the population, Georgia, for instance, with about one-fourth the population of New York, having twice the number of sulphuric acid factories that New York had.

I am aware that the number of establishments in an industry is an unsafe criterion as to the magnitude or importance of that industry, but this feature has been chosen as lending itself most easily to graphic demonstration. I have, therefore, assembled, by geographic divisions, in Table VII, data for the quantity of sulphuric acid produced, and we find that inspection of this leads to much the same result as to that which was drawn from the consideration of the distribution of the establishments.

All investigations show that there is an enormous extent of fairly well-populated area in this country yet awaiting development by the chemical engineer.

As a field in which costs may be diminished, attention may

TABLE V—IMPORTS OF MERCHANDISE, BY PRINCIPAL ARTICLES AND CLASSES, YEARS ENDING JUNE 30, 1902–1908

Order of Magnitude, 1908	ARTICLES	1902	1903	1904	1905	1906	1907	1908	
								Value	Per Ct. of Total
		Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	
1	Sugar	55,061,097	72,088,973	71,915,753	97,645,449	85,460,088	92,806,253	80,258,147	6.72
2	Chemicals, drugs, and dyes	57,723,622	64,351,199	65,294,558	64,779,559	74,477,137	82,997,914	73,237,033	6.13
3	Cotton, manufactures of	44,460,126	52,462,755	49,524,246	48,919,936	63,043,322	73,704,636	68,379,781	5.72
4	Coffee	70,982,155	59,200,749	69,551,799	84,654,062	73,256,134	78,231,902	67,688,106	5.67
5	Silk, unmanufactured	42,635,351	50,011,050	46,100,500	61,040,053	54,080,504	71,411,899	64,546,903	5.40
6	Hides and skins	58,011,168	58,031,613	52,006,070	64,764,146	83,882,167	83,206,545	54,770,136	4.59
7	Fibers, vegetable, etc., manufactures of	39,036,364	39,334,521	40,308,837	40,195,406	51,437,581	67,422,557	54,467,572	4.56
8	Wood, and manufactures of	24,445,599	28,746,271	26,984,353	29,564,323	36,532,706	42,969,941	43,527,982	3.64
9	India rubber and gutta-percha, crude	25,652,977	31,004,541	41,049,414	50,729,873	46,035,685	60,206,418	37,753,266	3.16
10	Fruits and nuts	21,480,525	23,726,636	24,435,854	25,937,456	28,915,747	35,867,160	37,354,742	3.13
11	Fibers, vegetable, etc., unmanufactured	31,545,962	34,462,513	37,814,285	38,118,071	39,360,290	42,239,358	35,493,083	2.97
12	Silk, manufactures of	32,640,242	35,963,552	31,973,680	32,614,540	32,910,590	38,653,251	32,717,668	2.74
13	Iron and steel, manufactures of	27,180,247	51,617,312	27,028,312	23,510,164	29,053,987	40,587,865	27,607,909	2.31
14	Tobacco, and manufactures of	17,706,493	20,579,120	20,073,346	22,145,846	26,590,706	30,192,375	27,267,913	2.28
15	Tin, in bars, blocks, and pigs	19,461,850	23,618,802	21,486,311	23,378,471	30,932,998	38,117,459	25,295,061	2212
16	Copper, manufactures of	10,968,948	17,505,247	18,215,442	19,942,511	25,835,502	39,428,687	24,462,663	2.05
17	Wool, unmanufactured	17,711,788	22,152,961	24,813,591	46,225,558	39,068,372	41,534,028	23,664,938	1.98
18	Spirits, wines, and malt liquors	15,246,640	17,171,617	16,662,702	17,652,323	19,257,590	22,104,235	20,771,804	1.74
19	Wool, manufactures of	17,384,463	19,546,385	17,733,788	17,893,663	23,080,683	22,321,460	19,387,978	1.62
20	Oils	9,300,198	12,283,957	11,179,442	11,593,520	13,723,948	17,068,777	18,292,393	1.53
21	Furs, and manufactures of	15,623,601	15,301,912	14,763,002	18,306,302	21,855,682	21,884,034	15,918,149	1.33
22	Diamonds and other precious stones	23,348,225	31,479,223	22,964,119	33,313,931	40,247,010	42,878,901	16,642,634	1.39
23	Articles, the growth, etc., of the United States, returned	5,815,628	7,170,573	9,899,470	9,079,124	11,134,912	11,833,983	16,599,766	1.39
24	Tea	9,390,128	15,059,229	18,229,310	16,230,858	14,580,878	13,915,544	16,309,870	1.37
25	Cocoa, crude, and leaves and shells of	6,656,504	7,820,087	8,873,709	8,577,649	8,697,515	13,376,562	14,257,250	1.19
26	Cotton, unmanufactured	11,712,170	10,892,591	8,541,510	9,414,750	10,879,592	19,930,988	14,172,241	1.19
27	Leather, and manufactures of	11,317,785	11,294,167	11,100,215	11,666,233	15,140,926	20,393,533	14,127,347	1.18
28	Earthen, stone and chinaware	9,680,156	10,512,052	12,005,014	11,659,723	12,877,528	13,706,790	13,427,969	1.12
29	Fish	8,527,097	8,635,583	9,889,697	10,498,076	11,607,602	12,335,988	12,292,770	1.03
30	Paper, and manufactures of	4,223,125	4,733,036	5,319,086	5,623,638	6,998,761	10,727,885	12,223,058	1.02
31	Meat and dairy products	3,510,696	4,703,536	4,197,466	4,253,414	5,117,054	6,768,432	8,877,183	.74
32	Vegetables	7,039,835	4,581,355	7,008,602	3,983,272	5,092,932	5,728,472	8,289,068	.69
33	Toys	4,023,670	4,232,074	4,977,389	4,964,457	5,887 863	6,993,561	7,206,423	.60
34	Breadstuffs	2,580,295	3,023,160	3,247,503	6,557,347	4,513,667	5,892,968	7,138,214	.60
35	Copper ore	14,003,840	3,385,524	3,466,381	4,892,961	6,727,861	8,296,328	7,057,080	.59
36	Metal, and manufactures of, not elsewhere specified	6,223,383	7,057,202	7,092,125	7,050,118	7,888,565	10,325,446	6,768,637	.57
37	Glass and glassware	6,205,052	7,255,879	6,583,168	5,948,839	7,507,823	7,596,631	6,570,123	.55
38	Seeds	3,252,152	2,831,279	3,587,469	3,457,619	5,388,043	6,404,776	6,371,470	.53
39	Books, maps, engravings, and other printed matter	4,133,215	4,323,938	4,529,187	4,589,858	5,599,948	6,451,309	6,036,693	.51
40	Coal, bituminous	5,310,450	10,562,185	5,043,824	3,713,748	4,367,750	4,184,541	5,123,862	.43
41	Fertilizers	2,426,758	3,100,276	3,503,726	4,524,700	4,446,360	5,341,430	4,970,461	.42
42	Hats, bonnets, and hoods, and materials for	3,050,478	3,871,278	3,963,043	4,379,473	4,571,184	6,820,259	4,852,548	.41
43	Rice	2,926,921	3,061,473	3,073,430	2,010,966	3,082,203	4,392,146	4,798,553	.40
44	Animals	4,624,531	4,533,845	3,129,609	3,337,454	3,914,382	4,344,282	4,777,459	.40
45	Household and personal effects	2,934,244	2,856,007	3,040,523	3,263,384	3,941,875	3,835,354	4,446,187	.37
46	Feathers and down, crude, not dressed, etc.	2,032,566	2,476,659	2,742,018	2,036,791	2,970,260	4,401,131	4,360,721	.37
47	Matting for floors, etc	3,817,866	3,780,050	3,609,795	3,600,088	3,831,436	3,769,202	4,333,044	.36
48	Art works	3,516,536	4,310,315	3,286,262	4,381,324	4,908,782	5,867,265	4,310,767	.36
49	Cork wood, or cork bark, and manufactures of	2,464,934	2,567,580	2,295,138	2,738,319	3,313,306	4,063,982	4,249,006	.36
50	Lead, in ore	4,497,360	4,073,099	3,374,661	3,616,476	3,534,876	3,352,534	4,147,720	.35
51	Paper stock, crude	2,770,255	3,015,084	2,900,713	3,796,595	4,374,464	5,580,528	3,675,926	.31
52	Spices	3,685,242	4,815,125	4,366,008	4,583,356	5,188,116	5,113,000	3,591,537	.30
53	Hair, and manufactures of	2,055,536	2,775,084	2,727,062	3,428,404	3,854,349	3,604,599	3,561,012	.30
54	Iron ore	2,362,544	2,351,278	1,593,279	1,670,683	2,728,854	3,360,449	2,949,462	.25
55	Clocks and watches, and parts of	2,460,324	2,672,310	2,990,474	2,966,495	3,105,136	3,593,173	2,922,142	.22
56	Cement	1,478,452	3,607,666	2,052,952	1,355,696	1,394,447	3,778,114	2,100,598	.18
57	Bristles	2,047,331	2,654,604	2,367,301	2,370,498	2,695,746	3,261,877	2,097,777	.18
58	Jewelry, and manufactures of gold and silver	2,642,345	2,007,433	2,048,821	1,303,652	1,739,953	1,779,527	1,672,275	.14
	All other articles	50,313,903	57,875,712	52,552,007	57,131,870	73,919,068	88,063,181	74,169,712	6.21
	Total	903,320,948	1,025,719,237	991,087,371	1,117,513,071	1,226,562,446	1,434,421,425	1,194,341,792	100.00

be called to the savings of waste. So much has been said on this subject that I hesitate to dwell upon it lest I weary you. But I venture to suggest that one remedy for waste, which has not been so markedly dwelt upon as it deserves, is by a change in location, and I take as an example of this the gas industry.

I have long looked upon our present custom of transporting coal long distances to be converted into gas as uneconomic, for a not inconsiderable quantity of coal is burned to provide the energy with which to haul this coal. Not only that, but, since the gas constitutes but a very small percentage by weight of the coal, there is a considerable waste in hauling the coke, with its ash and the by-products. Further, to provide for emergencies, large stocks of coal must be accumulated in advance at the gas

TABLE VII—QUANTITY OF SULPHURIC ACID PRODUCED IN THE UNITED STATES BY GEOGRAPHIC DIVISIONS 1905 AND 1900

Division	1905	1900
	Tons	*Tons*
United States	1,869,437	1,548,123
North Atlantic	768,647	734,669
South Atlantic	540,593	520,575
North Central	349,906	153,979
South Central	141,107	87,665
Western	69,184	51,235

works, and as coal, particularly gas coal, begins to deteriorate as soon as it is removed from the mine, there is a very considerable loss going on all the time from this cause. Further, as the by-products or residuals are now purchased in the crude state in relatively small quantities at the different gas works, a large part of their value is consumed in collecting and transporting them to central refineries.

By producing the gas at the mine and shipping it by pipe line the cost of haulage on the coke, with its ash and crude by-products, is saved. The wastage of coal by weathering is saved. The cost of collection and transportation of the crude residuals is saved. Such coke as is not needed for industrial purposes can be converted in producers into gas which, by means of internal-combustion engines, can be used in generating electricity for distribution, and the ash from this coal can be put into the mine for use as a filler in place of coal.

It is evident that gas can, under these circumstances, be made and delivered at a much less cost than is the case at present, though it may be necessary after long travel to enrich it near the point of consumption. Furthermore, the valuable areas now occupied by gas plants in our cities can be given up to more concentrated industries and cheap country lands be substituted for them.

I venture further to suggest that frequently an urgent reason for saving waste is to suppress a nuisance, for I do not hesitate to assert that the existence of a public nuisance is evidence of the existence of an economic waste.

Almost at the outset of my professional life, in 1872, I became involved in the famous Miller's River nuisance case, and it fell to my lot to examine, on behalf of the citizens of Cambridge, Mass., the large slaughtering houses which were believed to be the cause of the nuisance, and to study the operations going on within them. The conditions were very complex and there were a variety of causes which led to the creation and maintenance of this most horrible and most extensive nuisance, but among other causes I found that the slaughtering houses had permitted much valuable blood and offal to escape into the stream and that, at that time one establishment alone was pouring into the river, in the water in which it had steamed its hogs, over 5 tons of gelatinous matter per week, and this was done in ignorance of the existence of this matter in the tank waters.

What I have found to be true regarding matter, I have also found to be true as regards energy, and I cite as an example the nuisance of "cannonading" in blasting, which is proof in itself of the use of unnecessarily excessive charges of explosives.

But in urging the abating of a nuisance or advising the saving of waste or the conserving of resources, we should not fail to point out that it can usually be accomplished only with added expense and that a profit can rarely be realized unless the operations are carried out on a quite considerable scale. In fact, it seems to be an economic law that only the rich can really save; that "to him that hath shall be given," for the poor must pay the price of much subdivision and the consequent cost of much handling and a multiplicity of containers.

In fact, we should make it plain that the advocacy of the saving of waste in manufacture and of conserving our resources necessarily implies the use of great aggregations of capital and the carrying on of large-scale operations under a single management. It means the application of methods such as have been applied with great success in the manufacture of hog products or in the refining of petroleum. In dealing with coke at the census of 1905 I found that of the 37,376,251 tons of coal coked in the United States in that census year only 3,317,585 tons, or 8.9 per cent, were coked in by-product ovens, and I estimated from the yields and values of the by-products which were recovered that had all the coal been coked in by-product ovens there was a possible saving of $37,492,136[1]. This is an enormous amount to save in a single industry in a single year, and if the saving could be made an accomplished fact it would go far toward wiping out that humiliating account against us in our imports of "chemicals, drugs and dyes." But I have never failed to recognize the fact that this could only be accomplished by those controlling large capital, and that it meant the "killing off" of a large number of minor establishments, and I have further recognized the fact that the apparent savings set forth could not be realized until the charges against the more costly plant had been satisfied, nor until the market had been so readjusted that it could absorb this greatly increased output of by-products.

As an example of the commercial advantage resulting from the abating of a nuisance I cite the instance of Ducktown, Tenn., whose smelters have for decades been notorious offenders. I will not repeat to you the details by which their devastating sulphurous fumes have been converted into valuable merchandise since they have been so well set forth in current literature, but will simply note that, by report, this saving has resulted in the suspension of a number of the sulphuric acid works in the contiguous region, and I am ready to believe this report to be true, for I look upon this result as a natural consequence of the operation of a wholesome law in economics.

However, all of the endeavors avail but little so long as we remain a dependent nation, which the quantity of manufactured "chemicals, drugs and dyes" imported by us indicate that we are, and especially while we import over $7,000,000 worth of coal-tar products and nearly $2,000,000 worth of ammonium sulphate as we did in 1908, and yet allow $37,000,000 worth of the by-products produced in the coking of our coal to be wasted. It is evident that there is still a wide opportunity for the employment of the chemical engineer in developing our chemical industries.

I find that I have been led to devote my attention to the chemical industries of the United States when you have asked me to treat those of America. I have, however, limited myself, not because I consider our country America, but because of the limited amount of information that I have been able to secure relative to the other countries in North and South America. Such as is available for Canada is found in a paper by Dr. W. R. Lang, published in the *Transactions* of the Canadian Institute for 1904, from which it appears that, in 1903, salt was produced in the Dominion to the value of $334,000, and arsenic, in 1901, to the extent of 1,347,000 lb.

Sulphuric acid was produced in Quebec, Ontario and British Columbia, but neither the number of factories nor the extent of the output is given. However, in treating of the plant at Ontario, which produced about 15 tons of acid per day, it is

[1] Bull. 65, U. S. Census of Manufacturers; 1905, p. 18.

stated that imported brimstone was used as the raw material, and this in the face of the fact that Canada bounds in pyrites.

The wood distillation industry flourishes in that country, the plant of the Lake Superior Power Company being, it is said, the largest retort plant in the world, but no statistics of production are supplied. Ammonia liquor was produced to the extent of 235,000 lb. of 28° B strength, a larger part of it being exported.

Soap was produced by some 15 concerns, employing about 2000 hands, the value of the product in 1902 being approximately $3,000,000. Glycerine was obtained from the soap lyes, one works being capable of treating 10,000,000 lb. of lye annually. Petroleum refining was carried on at Sarnia, the factory being able to treat 60,000 barrels of crude oil per month. Calcium carbide was made in two works, carborundum and graphite in one. There was a limited manufacture of fine and heavy chemicals. This about completes the tale for Canada.

My efforts to obtain information relative to the Central American and South American States have been less successful, though I have searched the literature and consulted officials from and to these countries. "The Statistical Abstract of Foreign Countries," recently published by Mr. O. P. Austin, Chief of the U. S. Bureau of Statistics, covers the exports and imports of these countries for a decade, and it appears to be the only authoritative and detailed report concerning them, yet a painstaking search of the tables of exports for each of these Central American and South American countries shows no other chemical items than borate of lime, iodine, and nitrate of soda from Chile; charcoal from British Guiana and Argentina; fermented and distilled liquors from several of the countries, especially from the West Indian Islands; and dyestuffs and extracts from a number of States.

Literature relating to the commercial resources and industrial activities of the Pan-American republics, other than the United States, is apparently quite meagre, and information regarding their industrial activities appears not to have been collected either by the countries themselves or by students of commerce and industry. It does appear, however, from what information can be obtained, that the resources of these countries are in an undeveloped condition and that these countries present an almost virgin field for development by the chemical engineer.

I have myself attempted to inspire one such development, for at the outset of the undertaking of the construction of the Panama Canal by the United States, I advised that dynamite, which has been consumed in enormous quantities in the excavation work, and the manufactured "raw" materials of its manufacture, be made upon the Isthmus. The easy access to the nitrate of soda deposits of Chile, making but a brief water transportation necessary for delivery, and the existence of pyrites in great abundance in the vicinity of the Isthmus, making the production of sulphuric, and hence mixed, acids easy and simple were a few of the many advantages which would follow the adoption of this plan. But not the least would be the civilizing influence which chemical manufacture always exerts. It is unnecessary to say that up to the present I have been unsuccessful in my endeavors to introduce chemical manufactures into the Central American States, but I trust that you, who have done me the honor to listen to me, may succeed where I have failed.

GEORGE WASHINGTON UNIVERSITY,
WASHINGTON, D. C.

The Colorado School of Mines senior classes in mining and metallurgy are now on the annual trip of inspection to the larger mining and metallurgical centers of the West. The trip began April 25 and will end May 23. The Salt Lake City district in Utah and the Butte and Anaconda districts in Montana are the principal points visited. The more important centers in Colorado are usually inspected on short trips at other times during the year.

The Tube-Mill Circuit and Classification.*

BY G. O. SMART.

In view of the increased attention which has been paid to classification for tube-milling, it is of interest to note the results of work carried out on the Rand for the past year. It is now generally admitted that for most efficient tube-milling it is necessary to maintain constant conditions as regards tonnage and moisture in the pulp entering the tube-mill.

A general arrangement of the tube-mill circuit and classification system as used on the Rand is shown in Fig. 1. With this system only those particles in the tailing pulp can overflow the classifier and pass away to the cyanide plant, which are not sufficiently heavy to fall through the classifier and so pass into the tube mill. Thus the particles of richer and specifically heavier pyrites are reduced to a finer state of division before leaving the crushing plant than the poorer and lighter silicious grains, so that the tube-mill works mostly on that portion which best repays to grind. To further obtain full efficiency of the tube-mill the outflow should contain a fairly large proportion of coarse grains, which will be again elevated to the classifiers and return to the mill, while the portion which has been sufficiently finely comminuted by its first passage through the tube-mill will overflow the classifier. The circuit, as shown, also serves as an efficient trap for floured mercury and amalgam.

The rapid increase in the number of cone classifiers employed on these fields, and elsewhere in mining districts, in place of the old-fashioned wooden pyramidal spitzkasten and spitzlutten, is due to their greater efficiency, inasmuch as the length of their overflow, which is more than three times as large as that in the usual pyramidal classifier, reduces the velocity of the stream in inverse proportion, so that more efficient settlement is obtained. The use of conical classifiers with peripheral overflow launders naturally involves a central inflow, in place of the side inflow and overflow over the opposite side usual with pyramidal classifiers. This arrangement reduces the velocity of the overflowing pulp and consequently allows more tranquil and better settlement.

The cone classifiers, shown in Fig. 2, are considerably larger than those in use elsewhere on these fields, being 6 ft. in diameter and 9 ft. deep. This is in accordance with the principle of employing units proportional to the size of the plant, and likewise because each tube-mill having but one classifier, its superficial settling area must be sufficient to ensure the settlement at once of all grains in the pulp entering which require further crushing. The principle of operating this classifier differs from that of other hydraulic classifiers in that it must be operated with a considerable depth of settled sand. It will likewise be seen that the upper and lower portions of this sand are separated by a disk near the bottom, of which the edges are 2½ in. from the side of the cone.

In its original form this disk was serrated and was supported by the sides of the cone, but a plain disk supported by projecting arms extending to the sides of the cone, as shown in Fig. 2, is now used. When a wooden disk is used weights are required, also shown in Fig. 2, in order to keep the disk in position until the cone fills up with sand. This disk, or partition, is termed a diaphragm on account of its dividing the upper portion of the cone from the lower and, as will be seen, its function is entirely different from baffles as used for diverting the course of the stream of fluid pulp. While supporting the shifting mass of descending solids, it permits of a continuous flow between its periphery and the sides of the cone, and at the same time prevents a vertical channel from the top of the cone forming through the mass of solids to the outlet, which would allow thin fluid pulp to descend and escape.

Further, the diaphragm relieves the pressure of the mass upon the outlet at the apex of the cone, and, therefore, should be made fairly strong. The relieving on the outlet of such di-

*Abstract of a paper read before the Chemical, Metallurgical and Mining Society of South Africa. The full paper is published in the February (1910) issue of the *Journal* of the Society.

rect pressure prevents the undue packing of the solids at the apex, which would result in the pulp issuing very slowly, even with a free vertical discharge. This slow rate of underflow would necessitate a very large outlet at the bottom to pass the required tonnage, with consequent liability to formation of a central channel, or bore, and sudden discharge of a very large and unmanageable volume of fluid pulp. Such an underflow, if unchecked, speedily results in the discharge of all the solids in the cone owing to increased velocity. Further, if any attempt is made to run even a moderately thick pulp underflow from a classifier without using a diaphragm solids settling on the sides are liable to periodically slip and fall like miniature landslides, and thus, even if the outlet is not completely choked, the tonnage and ratio of water to solids is continually varied.

Since it is obviously impossible to observe what is happening inside a cone classifier the foregoing explanations are advanced from continuous observation upon the behavior of such appliances. The action of the diaphragm is difficult to understand and is subject to different explanations, but as regards the result that it ensures a steady underflow, in large volume, of thick pulp there is no doubt. The fact that the particles of sand must descend round the periphery of the diaphragm ensures a more uniform settlement of the solids in the cone than if no diaphragm were used.

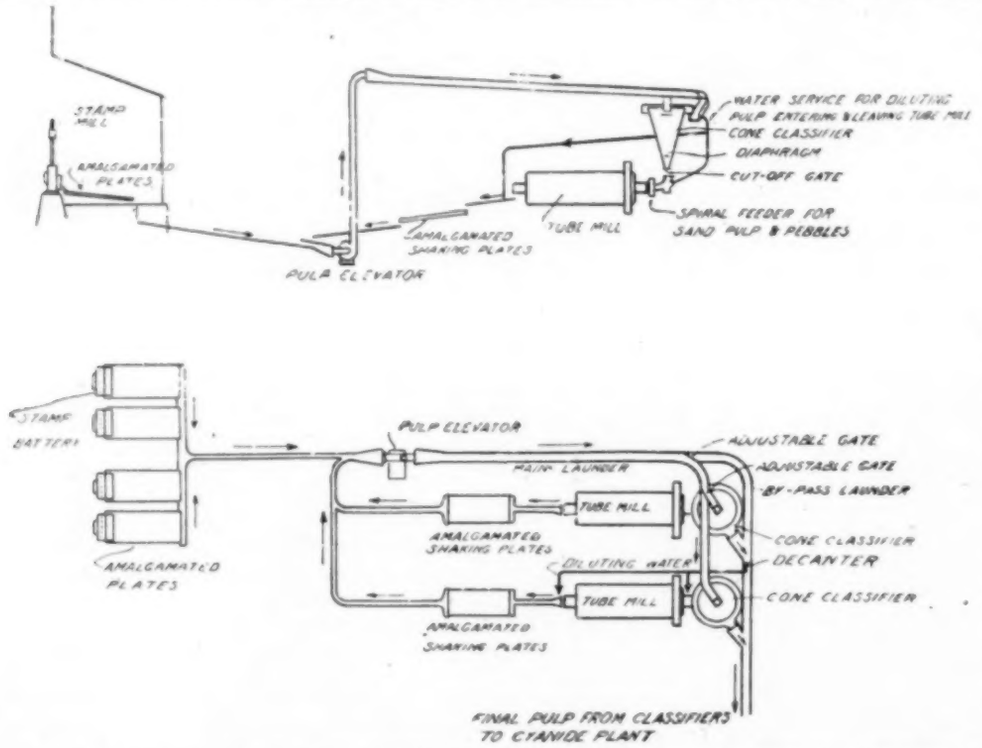


FIG. I.—TUBE-MILL CIRCUIT, WITH SINGLE CONE CLASSIFIER, AND DIAPHRAGM FOR EACH TUBE MILL.

The upper surface of the settling solids is concave, the edges being higher at the side of the cone. Since the coarser grains naturally settle nearer the center than the finer grains, and since the former constitute the bulk of the settled particles, it follows that in the upper portion of the cone, the faster downward movement of the descending solids is nearer the center than the side of the cone. At the same time particles of insufficient sizes or density to settle near to the center, but which the velocity of the current is insufficient to transport over the edge, settle before overflowing and gradually creep down the sloping side of the cone.

If the ratio of water to solids in the pulp entering the classifier decreases, the finer particles in the settled solids accumulate at the side near the top until the cross-sectional area of the basin is of such dimensions that the velocity of the pulp flowing over its edge, and over the edge of the cone, is sufficient to carry away all particles of such a size as are not specifically heavy enough or large enough to descend. But if with a decrease in the volume of water entering the classifier there is likewise a decrease in the tonnage of solids, or in the average size of particle in the pulp, both the overflow and underflow under these conditions are correspondingly finer. If, however, while the volume of water is decreased, the tonnage and coarseness of the solid particles remains the same, and merely the ratio of water to solid reduced, then the average fineness of both overflow and underflow remain constant.

Similarly, if the volume of pulp entering the classifier is increased, but the tonnage of solids and average size of particle remain the same, only the ratio of water to solid being raised, the cone again automatically adjusts itself to the changed conditions and yields the same grading of overflow and underflow as before. This is due to the area of the basin being increased by extending its edges toward the side of the cone and thereby reducing the velocity of the overflow stream at the point where the solids are discharged to the same as before. If the average size of particles in the pulp entering the classifier be greater, both overflow and underflow are proportionately coarser.

In the practical operation of classifiers, it is not only necessary that a thick underflow of the desired tonnage be secured, but that there should also be an equal volume of pulp of the same consistency delivered to each classifier, as otherwise classifiers receiving more than their proportionate share of the total pulp or solids will overflow a coarser product than others receiving less. It is, therefore, necessary that the overflow of each classifier should be sampled and tested, to secure uniformity. From the foregoing it will be apparent that unless the volume of pulp entering is greater than the capacity for which the cone was designed, which will result in the velocity of the stream being greater than will allow of the settlement of the bulk of the desired particles, it follows that the classifier will automatically adjust itself to all conditions. The object of the horizontal baffle shown near the top of the cone, Fig. 2, below the inlet, is to prevent the force of the stream disturbing the settled solids and to divert the flow of pulp in a horizontal direction towards the periphery of the cone.

Owing to the low percentage of moisture and consequently viscous nature of the underflow it is essential that it should have the freest possible discharge from the outlet of the classifier. Any attempt to discharge the underflow through a pipe with a right-angle turn, or through a curved pipe attached to the bottom of the cone, or even through a vertical pipe of the same diameter as the usual outlet, will be unsatisfactory. The best method at present known for discharge of the underflow is a free vertical fall from the outlet at the apex of the cone through a nozzle, as shown in Fig. 3. It will be observed that this nozzle is practically a continuation of the sides of the cone, and terminates in a sharp edge so that in no portion are there parallel sides. The friction is consequently reduced to a minimum. This nozzle constitutes the wearing portion of the outlet.

and consists of a simple piece of hard cast-iron, which lasts about three weeks, and can be readily replaced at the cost of a few pence.

To shut off the underflow of the cone when required, or to regulate the flow, several devices are suitable, one of which, as shown in Fig. 3, does not obstruct the free vertical discharge. The diameter of the outlet to the classifier, shown in Fig. 3, is 2 3/16 in., which will pass about 400 tons of sand with 26 per cent. of moisture in 24 hours. This large size is required on

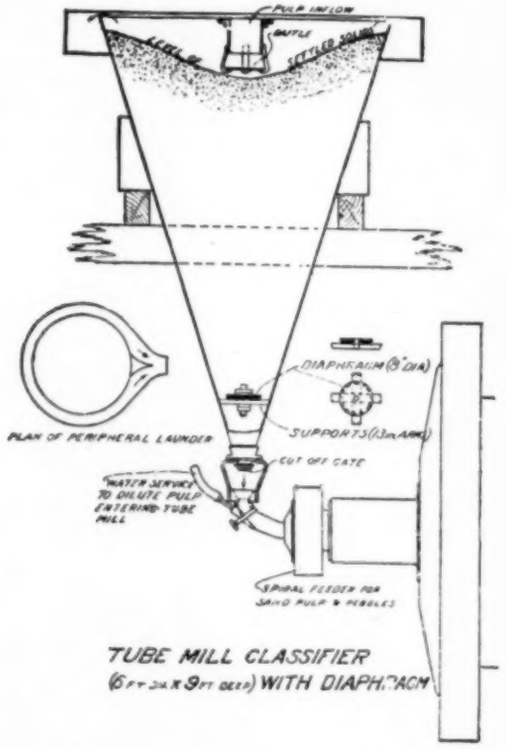

PULP INFLOW
BAFFLE
DIAPHRAGM (8" DIA)
SUPPORTS (1/2" ANG)
PLAN OF PERIPHERAL LAUNDER
CUT OFF GATE
WATER SERVICE TO DILUTE PULP ENTERING TUBE MILL
SPIRAL FEEDER FOR SAND PULP & PEBBLES
TUBE MILL CLASSIFIER
(6 FT DIA X 9 FT DEEP) WITH DIAPHRAGM

FIG. 2.—TUBE-MILL CLASSIFIER WITH DIAPHRAGM.

account of the slow rate of the flow of the viscous pulp. Incidentally, the wear on the nozzle, by abrasion, caused by such slow rate of flow, is considerably less than with the usual type of spitzlutten, delivering pulp at a greater velocity.

The thick underflow described contains too little moisture for efficient tube-milling, and is delivered at so slow a velocity that the method of feeding the tube mill by means of the horizontal jet, as commonly employed, is impracticable. To ensure the delivery of such pulp into the tube mill it is necessary to employ preferably a spiral form of feeder shown in Fig. 2. The additional water required to thin down the pulp for efficient tube-milling is, of course, of some assistance in the delivery of the underflow into the interior of the tube mill. This water may be derived from the mill water service, or may be conveniently obtained from the upper portion of the stream in the tailing launder, in the latter case this water also serves to dilute tube-mill outflow before amalgamation, and is withdrawn from the upper portion of the tailing pulp, by means of a small adjustable decanter, placed in the launder, with an intake opening facing upstream, Fig. 1. The amount of water required is exactly regulated by valves, or cocks, on the pipes from the decanter.

With the contemplated removal of amalgamated plates from the stamp mill, and with very coarse crushing, the importance of continuous and reliable classification becomes very great, so as to prevent any but the very finest gold overflowing the classifiers and to ensure that nearly all the metallic gold liberated by crushing, shall reach the amalgamated plates in the tube-mill circuit. The settling area of a 6-ft. diameter cone, if 28.3 sq. ft., so that with the high ratio of tube mills to stamps, needed with coarse stamp milling, the settling area in the classifiers becomes proportionately large, and the liability for coarse particles of metallic gold to overflow the classifiers is thus reduced.

In consideration of what has been already stated, and by reference to the diagrams shown, it will be seen that several advantages are secured by the method of classification described. In the first place, the simplicity of the general arrangement and the fewness of the units involved are obvious, and consequently the initial cost of installation, attendance, and the liability to derangement are much reduced. The large outlet at the bottom of the single cone for such tube mill precludes the possibility of choking when an inclined ¾-in. mesh screen in the tailing launder is used, in place of the usual ¼-in. mesh, which latter necessitates continual labor in removing ore fragments and debris, under penalty of disastrous results. The saving in elevation by the use of a single cone may be of great importance, especially in an existing plant, when the fall available is insufficient to permit of the installation of the usual spitzlutte, launders and dewaterer for additional tube mills.

This has been illustrated at the Simmer and Jack, where the satisfactory installation of a sixth tube mill was thus rendered possible, without change of launders or pumping arrangements, as also at a mining company in Mexico. At this latter plant an additional tube mill (5 ft. x 24 ft.) was installed, and as little fall was available, there was erected as the tube mill classifier, a cone 4 ft. 10 in. deep and 4 ft. in diameter, with a diaphragm 8 in. from the apex, allowing 1.5 in. annular space between diaphragm and cone. This classifier was run completely filled with sand, and was fed from the battery at the rate of 240 tons of tailing per 24 hours, produced from screen of 256 holes per

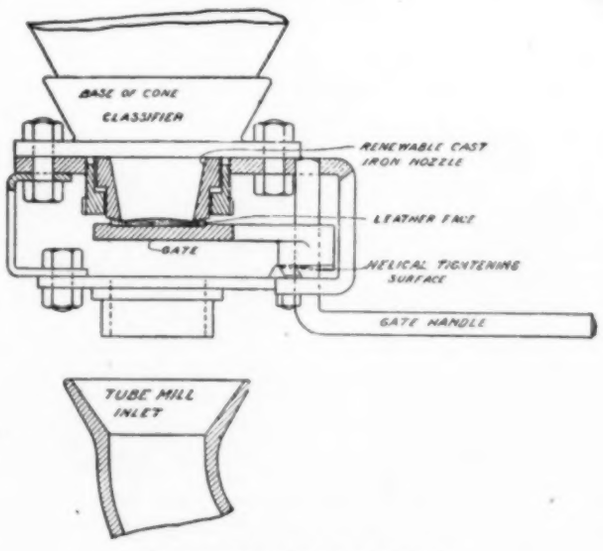


FIG. 3.—DISCHARGE OF UNDERFLOW.

square inch. The following were the results obtained from the classifier:

Gradings.	Inflow.	Overflow.	Underflow.
+ 30	18.5	0.5	34.5
+ 40	10.0	1.0	16.5
+ 80	21.5	8.0	33.5
+100	1.0	1.5	1.5
+150	12.0	11.5	8.0
+200	3.5	9.9	2.0
—200	33.5	68.5	3.5
Percentage of moisture.	90	93	34

The foregoing overflow is fairly fine, but if a finer final product were required, it would be necessary to reduce the volume of pulp entering the cone, or to employ a larger classifier. As under the conditions of this plant 38 per cent. of moisture gives a considerably higher tube-milling efficiency, than higher or lower dilution, a satisfactory tube-mill product was in this way secured, whereas the usual classifiers had failed to

reduce the moisture in the underflow below 48 per cent.

The following table represents the effect produced upon the efficiency of classification for tube milling, by a recent change at the Simmer and Jack plant, whereby the classification for four tube mills was converted from the ordinary pyramidal spitzlutten, launders and dewaterers, to a single cone per tube-mill single cone classifier having previously been installed for the other two tube mills.

Period.		Pyramidal Spitzlutten and Dewatering Cones. 1st to 8th Dec., 1909.	Single Cone Classifiers with Diaphragms. 1st to 8th Jan., 1910.
Tons ore milled		12,208	17,934
Grading analyses of tube-mill feed	+60	61.8	67.1
	+90	22.3	20.7
	−90	15.9	12.2
Grading analyses of mill tailing	+60	43.8	45.2
	+90	11.8	11.7
	−90	44.4	43.1
Grading analyses of final pulp entering cyanide plant	+60	10.9	7.4
	+90	16.0	15.9
	−90	73.1	76.7
Relative internal capacity of tube-mills		100	102.5
Tons—90 product per tube-mill, 24 hours		115.2	126.5
Relative tons—90 product per unit of tube-mill capacity		100	107.3

This comparison of grading analyses and efficiency would appear still more favorable, were it not that only two-thirds of the classification plant was changed, the remaining third having been changed previously to the single cone system. It will be seen from the foregoing that the tons of −90 mesh product per tube mill per 24 hours were raised by 11.3 tons, or allowing for 2.5 per cent. greater internal capacity of tube mills owing to longer average life of liners, the tube-milling efficiency was increased 7.3 per cent. This is due to the better separation in the classifiers of the coarser particles requiring regrinding, and to the thicker and steadier feed of pulp. The low percentage of −90 mesh product entering the tube mills from the single cone classifiers will be noted, as also the reduction of the +60 product from 10.9 to 9.4 per cent. in pulp entering the cyanide works. This is due to the fact that the low percentage of moisture carries down very little finely divided solids or slime.

Owing to the less labor and attention required by the classifiers, two men were transferred to other work.

New York Section American Electrochemical Society.

At the meeting of the New York Section of the American Electrochemical Society held on March 16 Dr. Fritz Zimmermann, of Newark, N. J., presented a paper on the decomposition of carbon monoxide in presence of catalytic agents and in the blast furnace, while Dr. Reston Stevenson of the College of the City of New York lectured on chemical reactions at electrodes. The former paper was published in our April issue, page 182, while the latter paper will be found elsewhere in the present issue.

The following officers of the section were elected for the ensuing year. Chairman, Mr. Elmer A. Sperry; secretary-treasurer, Mr. H. B. Coho. A motion of Dr. Baskerville, expressing the gratitude of the section to the retiring secretary-treasurer, Mr. Alois von Isakovics, for his indefatigable work of many years, was unanimously carried.

New York Section American Chemical Society

The program of a largely attended meeting of the section, held on April 8, was a symposium of papers on leather as follows: General outline of the industry, by Allen Rogers; the processes of bating, by Alan A. Claflin; vegetable tanning materials, by John H. Yocum; recent advances on chrome tannage, by Otto P. Amend; the coloring of leather, by F. E. Atteaux; oils used in the leather industry, by Edgar A. Prosser. Previous to that F. D. Dodge read a paper on methods of analyzing essential oils.

The next meeting will be held on May 6.

Modern Electroplating Plant.

At the works of the National Cash Register Company, Dayton, Ohio, is to be found an electroplating plant which for size, completeness, and general cleanly operating conditions may well be called a model, and quite on a par with the other high-grade equipment of the "National" company.

Practically all of the metal work used in connection with cash registers is plated, the outside of the cabinet for appearance's sake and the interior mechanism for protection against rust.

The Layout.—The plating department is on the fifth and top floor of one of the buildings, and occupies a floor space 540 x 60 feet. The sides of the building are composed mostly of windows 8 x 8 feet each, and these, together with the elevation, give abundance of light and ventilation. The latter is further improved by ten powerful exhaust fans in the side walls and four in the ceiling of the dip room.

In the main room are 105 plating tanks, each equipped with individual rheostat, voltmeter and ammeter, thus giving absolute control of the pressure and the current. Ninety-three tanks are devoted to "wire work"—that is, the plating of comparatively large pieces, rods, plates, etc., which are hung suspended by copper wires twisted around the cathode rod. The other twelve tanks are fitted with wicker-work baskets, which are slowly revolved in the electrolyte. Each basket has capacity for two or three pailfuls of small inside parts, bolts, nuts, etc.

In addition to the plating outfit, several cleaning tanks are provided. These are connected direct to the line, without meters or rheostat. The castings to be cleaned are cathodes, as in the plating process, and the violent bubbling of hydrogen speedily loosens up the oil, polishing powder, scale, and other discolorations. Iron and steel only are treated in this way, as an automatic method for satisfactorily cleaning bronze does not yet seem to have been discovered. Bronze castings are soaked in soapy water, scrubbed with a hand brush and dipped in weak lye water.

The acid dipping room, 20 by 60 feet, contains one elliptical dipping tank at which two gangs of men can work simultaneously, and one straight tank for one gang.

Pickling tanks for hydrofluoric, sulphuric and muriatic acid pickles are in a smaller room set apart from the other sections, and the fumes are carried off by fans.

The laquer room, 120 by 60 feet, is used in coating the register cabinets or outside casings. It contains ten glass ovens 7 by 20 feet, steam heated, for baking the laquer.

A complete chemical laboratory in another building has rendered valuable service in the plating department, and has also effected a considerable economy in the operation of the entire works.

Solution for Various Finishes.—The following plating solutions are employed:

For nickel, the double sulphate of nickel and ammonia is used, 30,000 gallons being in use.

For copper, (a) copper cyanide and (b) copper sulphate are employed, the quantities being 2600 and 6000 gallons, respectively.

For silver, the cyanide of potassium and chloride of silver is used, 800 gallons being the amount of solution.

For zinc plating, 4000 gallons of commercial sulphate of zinc acidulated with a little sulphuric acid are used.

For cleaning, crude potash and carbonate of potash and carbonate of soda are employed.

The total amount of standard solutions in use is 47,200 gallons, besides several hundred gallons of other solutions which are maintained for experimental purposes.

Notes on Methods.—The method of running through a piece is about as follows: The finished casting is received from the machine shop and dipped in a mixture of sulphuric and nitric acid to remove the scale and stains; then, if a cabinet part, it is sent to the polishing room to be scratchbrush polished and buffed. It is then returned for plating.

Nickel plate can be applied direct to any metal without a preliminary coating of copper, as was formerly thought necessary.

A very low voltage is being used for nickel plating, 1¾ volts on wired work. This is to avoid pitting and to make a softer coat which will take the polish better. The time needed is from one hour on cabinets to three hours on interior parts which receive considerable wear.

Zinc, on the other hand, can be put on very rapidly, 6 volts being used on wired work and about ten minutes being required.

One tank of zinc plating work will keep one man constantly busy. Eight to ten bolts are used on barrel galvanizing.

Copper plating requires first a cyanide solution to act as a "binder" that is to form a preliminary alloy to which the first coating will adhere. This goes on slowly, but about one minute on brass castings will be enough for the coat. Iron and steel take longer.

A transfer is then made to the faster acid sulphate solution for the heavy run.

PLATING PLANT OF NATIONAL CASH REGISTER CO.

When the copper is to receive an oxidized finish the piece, after removal from the sulphate tank, is washed in clear water and dipped in pentasulphuret of potassium (the commercial "liver of sulphur") long enough to get a blue-black color.

It is taken out smutty and is then scratchbrushed with a brass brush in order to bring out the luster of an oxidized finish.

The high parts of the work are then finally relieved with a felt or cotton buff wheel so as to bring out the contrasting copper effects.

Silver plating is used largely on the counter wheels to give a greater contrast with the black lettering. The silver coating is put on in about five minutes after a heavy base coat of nickel of some half-hour's time has been deposited.

Low-Voltage Generators.—The electrical equipment to supply the large amount of current needed is rather interesting, as it includes machines of various makes and different age.

Six direct-current motor-generator sets are used, the line voltage running 225 volts and the speeds from 450 to 850 revolutions per minute on the different sets.

The list is as follows:

Amps.	Volts.	Winding.	Maker.
4000	6-12	Compound	Jantz & Leist Electric Co.
3000	6	Shunt	Zucker & Levett & Loeb Co.
1500	8	Compound	Jantz & Leist Electric Co.
1400	6	Shunt	Eddy Electric Co.
1000	6	Compound	Burke Electric Co.
400	6	Compound	Jantz & Leist Electric Co.

The Zucker & Levett & Loeb 3000-ampere set has been in satisfactory service for the last seven years, and the 1400-ampere Eddy set for 16 years. Each machine has required practically no repair, and is apparently as good as when new. The other machines have not yet had as good an opportunity to demonstrate their long life.

The latest addition to the equipment, as well as the largest and most recent in design, is the 4000-ampere machine built by the Jantz & Leist Electric Company, of Cincinnati, Ohio. The overload capacity of this unit is 50 per cent, which brings the output to 6000 amperes. There are several interesting features connected with this machine, which may be mentioned.

The set, together with switchboard and control apparatus, is installed in a small frame housing erected especially for it on the roof of the main building, where it is removed from the acid fumes and has a generous supply of fresh air. The arrangement has proved so satisfactory that the other machines are to be moved up also. The motor-generator set is constructed in three sections, a 100-hp, 225-volt motor driving the two generators, one on either side, through flexible leather couplings. The normal rating of each generator is 2000 amperes at 6 to 12 volts, and it is compound wound. This winding has been found more satisfactory than straight shunt, as it is impossible to locate all the supplied tanks near enough to the generators to prevent a considerable voltage drop on full load.

A few advantages of the double generator arrangement are the following:

Better efficiency on light loads, as one section may supply all the current and the other run with the field off, so that the latter then remains unloaded.

Two voltages furnished, which is necessary when work of different classes, such as zinc and nickel, is being done.

High voltage obtainable. The two machines may be conveniently connected in series to furnish 24 volts. This may be useful in cleaning wood, though as at present arranged 12 volts is used and considered satisfactory.

When the rearrangement of the various generators is completed it is intended to use one end for cleaning and the other for plating operations.

Distinctive features of the design of the set might be mentioned, such as the elimination of the heavy cables found on most machines by the ring support for brush holders, use of carbon-gauze brushes instead of copper, etc., but it will be sufficient to note that since its installation some months ago the machine has been running with perfect satisfaction.

The plating department of the National Cash Register Company employs 98 men and is in charge of Mr. William Fraine, through whose courtesy we have been enabled to inspect the plant and secure the information for this article.

Improving the Output and Efficiency of Existing Electric Furnaces.

By Carl Hering.

The following case sometimes arises: Given an existing furnace, can it be improved in output or efficiency without a complete change of design? The object of the present article is to describe simple methods and rules by means of which it may readily be determined whether such improvements can be made by mere changes in the electrodes, and if so, how to calculate them, and whether it is worth while making them.

The electrode loss increases with the current, but is independent of the voltage; hence, the total voltage of the furnace should be made as high as possible and the current as small as possible.

The essential part of an electrode is the necessary part within the furnace wall, hence the terminal should be as close to the furnace wall as possible as every inch of electrode between the wall and the terminal is a useless, wasteful resistance. If the electrode requires to be fed, it is preferable, whenever possible, to feed it through the terminal so as to reduce the part between terminal and wall as much as practicable.

The other end, which may be projecting inside of the inside wall, does not necessarily represent an entirely dead resistance, because the heat generated in it either is added to that in the furnace or, if at a lower temperature, it at least tends to keep the furnace heat from flowing out. Such interior projections are not really parts of the essential electrodes, which are, or ought to be, only those parts which are within the walls.

The part within the walls should be surrounded with heat insulating material. The most perfect heat insulator is a body which is kept as hot as the body which it insulates. Hence, one of the best heat insulators would be a furnace wall in which the heat gradient is the same as that in the electrode. The necessarily poor thermal contact between the electrode and the surrounding wall will tend to act as a very high thermal resistance, which aids in this heat insulation.

The outside terminal should, in general, be allowed to get as hot as the conditions permit; the hotter, the less the electrode loss, but the larger the electrode.

Considering the length of the essential electrode to be that part within the walls, plus a part of that within the terminal, say, half the length of the terminal, and perhaps a short part of that portion which may project into the interior of the furnace, then if the electrode tends to burn out the interior of the wall, this length is too great, or, what is the same thing, the section is too small, or the current is too large. If, on the other hand, the furnace product is found to be chilled around the hot end of the electrode, the length is too short or the section too large, or the current too small. In either case the total electrode loss is greater than it need be. And when the product is being chilled by the electrodes the output of the furnace can be increased by lengthening the electrode or decreasing its section or increasing the current, as these changes increase the temperature of the hot end; hence, both efficiency and output can then be increased in this way.

The length being usually fixed by other considerations, the proper section in square inches is calculated by multiplying this length in inches by the current in amperes and by the factor s in the accompanying table for the given temperature drop of that furnace. With that new cross-section there will be practically no chilling of the product nor burning out of the walls around the electrode and the loss will be practically the least possible.

If the existing section is nearly equal to this value, then great accuracy in calculating it or in changing it to this exact size is unnecessary, as the loss increases but slightly for relatively much greater differences in the cross-section, provided the section is near to the best one; this is not the case, however, when the section departs considerably from its correct value.

	Temp. drop C.°	Temp. drop F.°	s	e	i
Carbon	1600	2912	0.00052	2.5	1920
	1800	3272	0.00048	2.7	2070
	2000	3632	0.00045	2.9	2200
	2500	4532	0.00040	3.3	2500
	3000	5432	0.00037	3.7	2700
Graphite	1600	2912	0.00022	1.5	4600
	1800	3272	0.00021	1.5	4700
	2000	3632	0.00021	1.5	4800
	2500	4532	0.00020	1.5	5000
	3000	5432	0.00020	1.5	5100

This minimum loss in watts for one electrode is then equal to the current multiplied by the factor e in the accompanying table for that range of temperature. For intermediate ranges of temperature it is sufficient for most practical purposes to make a proportionate correction of both e and s.

If it is impracticable or undesirable to make this change of the section of the electrode, as it may involve new terminals, the same results can be accomplished by changing the length instead. In that case, the new length should bear the same relation to the old section as the old length did to the new section. In other words, the results will be the same if the ratios of the lengths to the corresponding sections are the same.

Or, if it is more convenient to change the current instead of either the section or length, then the same result may be accomplished by making the current equal to the product of the factor i in the table and the existing section in square inches, divided by the existing length in inches. This, of course, changes the input and may, therefore, require a different source of current.

To find out whether there is any chilling action or unnecessarily high temperature within the walls, or to determine whether the possible gain in efficiency or output is worth making the changes, it is necessary to determine what the conditions of operation are in the existing furnace. This is not quite as simple to calculate because in the existing furnace there may be some heat flowing out of or into the furnace through the electrode.

Let L and S be the length and section of the existing electrode in inch units, and I the normal current which has been used; and let s, e and i again be the factors in the table. Calculate an auxiliary factor a so that $a = sL/S$. Then the total loss in watts through the cold end of each electrode will be

$$\text{watts lost} = \frac{e}{2}\left(\frac{1}{a} + aI^2\right)$$

and the watts of heat flow per electrode leaving or entering the furnace, if any, will be

$$\frac{e}{2}\left(\frac{1}{a} - aI^2\right)$$

which, if positive, means that this much of the power is leaking out of the furnace through each electrode, and is, therefore, chilling the product and is diminishing the output of the furnace; while if negative, it shows that it is flowing into the furnace and, therefore, is developing a higher temperature within the walls than in the furnace. The resistance loss, or I^2R loss, is equal to aEI^2 watts in each electrode.

By comparing the total loss thus determined with that which would be obtained after making the changes, it can be seen what the gain in efficiency would be and, therefore, whether it would be worth making the change. And by comparing the total watts set free in the furnace with those leaking out through the electrodes it will be seen how much the output could be increased if this outflow were stopped.

These last two formulas are not mathematically exact, but are no doubt sufficiently approximate for all practical purposes in the neighborhood of the correct proportions. It will be noticed that the current densities are not the determining factors and are not even involved; also that the two conductivities need not be known.

If the proportions are the correct ones for a normal current, it should be remembered that whenever the current varies it will either develop a high temperature within the walls or cause some chilling in the furnace. If the former is likely to injure the walls it is better to allow for a margin in the current at the expense of some chilling action. If the electrodes are carbon an appreciable improvement in the loss as well as a considerable reduction in the size and often also a more suitable shape can be obtained by using graphite, as the calculations given below will show; the reverse is probably never true. A correctly proportioned carbon electrode tends to be short and thick, sometimes impracticably so. Graphite electrodes tend to be more slender. Iron, and especially copper, are in turn better than graphite, but their substitution for carbon or graphite would generally require a complete change in the design of the whole furnace.*

Example.—The following numerical example will illustrate the above.

Given a 50-kw furnace operating with 1000 amp and 50 volts between outside terminals. Drop of temperature, 2000° C. Electrodes, carbon, 10 in. long and 20 sq. in. in section, they being supposed to have been calculated according to the old current-density rule of 50 amp per square inch. It is assumed that the voltage is fixed and cannot be further increased at the expense of the current.

From the table the value of s for carbon for 2000° drop is 0.00045, hence the new section for that length would be $0.00045 \times 1000 \times 10 = 4.5$ sq. in., or about one-quarter as large; the diameter would be about 2⅛ in. in place of about 5 in. From the table $e = 2.9$, hence, the total loss in each electrode would be 2.9 kw, or 11.6 per cent for both. Or, if it is desired to change the length instead of the section, the new length would be $10 \times 20/4.5 = 44.5$ in.; the loss will again be 2.9 kw.

The total electrode loss originally was 6.77 kw in each electrode, as obtained from the above formula, the quantity a being 0.000255, this left 36.5 kw available in the furnace; the total electrode loss was, therefore, 27.1 per cent, or over one-quarter, hence very high, more than twice what it could have been reduced to. Moreover, from the formula the leakage of heat from the interior of the furnace was 6.1 kw per electrode, which for both together amounts to just one-third as much as is available in the furnace itself, namely, 36.5 kw. This very large outflow of heat would undoubtedly chill a large part of the product in the furnace around the ends of the electrodes, hence reducing the hot zones greatly. The resistance loss in each electrode was only 0.66 kw.

The change to the smaller section would, therefore, result in a considerable saving of electrode material, a reduction of the total electrode loss of from 27.1 per cent to 11.6 per cent, a gain in available energy in the furnace of from 36.5 kw to 44.2 kw, or 21.2 per cent, and a large increase in the available hot space in the furnace as there would be no chilling action. Increasing the length to 44.5 in. would accomplish the same thing, except the saving in electrode material. The current density for the smaller electrode would seem to be very high, about 220 amp per square inch, but with a good water jacket this would probably not cause any trouble; if considered too high, then any desirable intermediate section could be used, in which case the length must be increased proportionately; the gain in power and output will, of course, be the same.

If instead of changing the section or length it is preferred to increase the current, then i from the table being 2200, the new current will be 4400 amp instead of 1000. This will increase the available heat in the interior of the furnace nearly five and one-half fold, making a 220-kw furnace of it, showing that the same furnace, just as it is, could have been increased enormously in output. This shows very strikingly how the older current density rule has misled us.

By using graphite instead of carbon the calculations will show that the electrode loss could be reduced to 1.5 kw per electrode, or nearly half that for carbon, or an additional saving of about 6 per cent; the section would be 2.1 sq. in., equal to about 1⅝ in. diameter, hence much smaller, and the available heat in the furnace would be increased about 6 per cent in addition. If, furthermore, the original carbon electrode were merely replaced by one of graphite of the same size, the proper current would be 9600 amp, or nearly 10 times the original, and as the efficiency would be considerably increased, the available energy in the furnace would be increased 13.1 fold besides making the total interior furnace space useful. While the current density would then be high, the writer has used still higher ones with graphite and experienced no trouble whatsoever.

PHILADELPHIA, April 7, 1910.

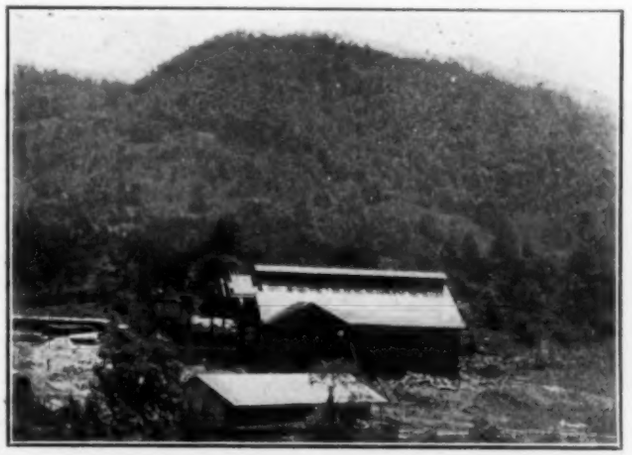
* Further information and details concerning the above methods of determining electrodes will be found in the following publications by the writer: *Proc.* Amer. Inst. Elec. Engr., March, 1910, page 285; two papers to be read at the coming meeting of the Amer. Electrochem. Soc.; *Transactions of* this society, Vol. 16, pages 265 and 317 (abstracted in this journal, Vol. VII. p. 514), this journal, March, 1910, page 128, and April, page 188; also a paper by A. E. Kennelly, *Proc.* Amer. Elec. Engr., March, 1910, page 267, on "Modifications in Hering's Laws of Furnace Electrodes."

Electric Smelting of Nickel Ore.

A New Electric Furnace Plant for Nickel Silicide in the South.

The development which is now being carried out by the Consolidated Nickel Company, at Webster, Jackson County, N. C., is particularly interesting as an example of the increasing industrial activity in the South, as well as a further instance of the advance of electric furnace methods into the realm of metallurgy.

The nickel ore deposits of Webster have long been known and for their utilization various processes have been proposed and tried in the past; they were essentially leaching methods, but all of them had to be abandoned, on account of excessive cost, after a shorter or longer trial.



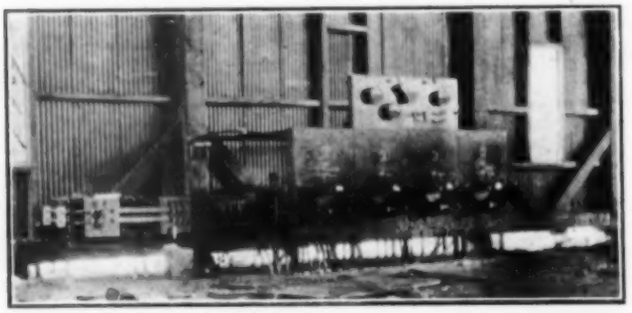
PLANT OF CONSOLIDATED NICKEL COMPANY.

The process now used is an electric furnace process, devised by Dr. Charles Theodore Hennig, of Brooklyn, after an extended investigation. The research in his laboratory was finished early in 1909 and the Consolidated Nickel Company, composed of New York capitalists, then began with the installation of electric plant and the erection of an electric furnace for testing the process on a large scale. In these tests, which have now been successfully concluded, electricity was generated by steam power, but in the ultimate commercial plant water-power will be employed, which is now being developed. For the information contained in the following article we are obliged to Dr. Hennig.

The Consolidated Nickel Company owns the mineral rights to 770 acres of land one-half mile from Webster; this town is

situated 3.5 and 4 miles from Dillsboro and Sylva, respectively, both places being on the Hurphy branch of the Southern Railway. The plant at Webster is to be connected by a spur with the Southern Railway. Hard wood is plentiful and labor is cheap, white labor predominating (farmers), the wages being about $1.50 per day of 10 hours. The cost of Tennessee coal is about $5 per ton at the plant, while wood costs $1.25 to $1.75 per cord delivered.

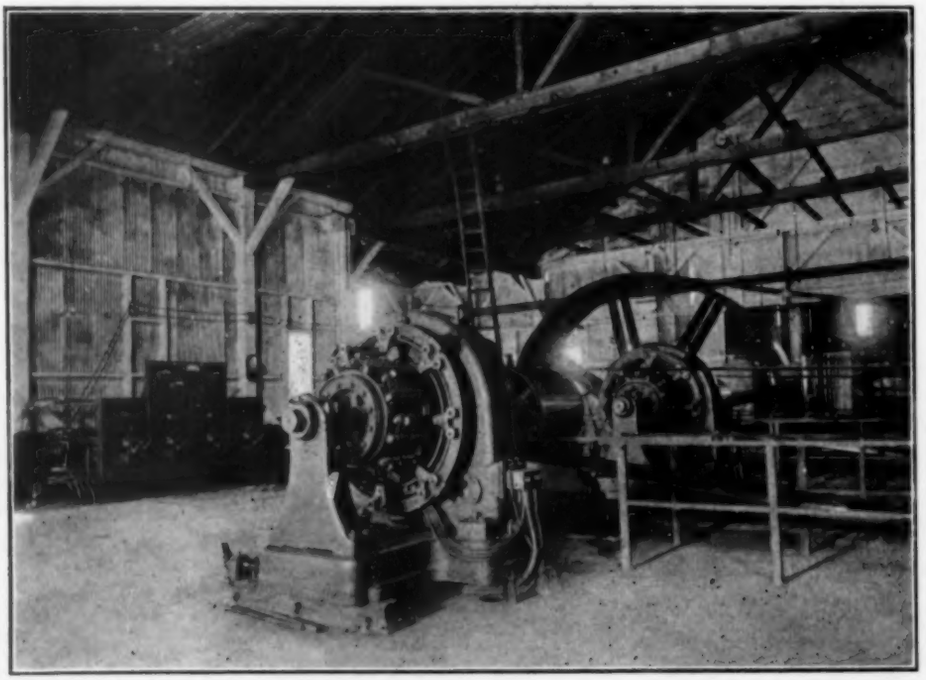
Nature of Ore.—The ore at Webster consists essentially of hydrated nickel-magnesium silicates, chiefly applegreen garnierite and brown dunite. The garnierite is richer in nickel, containing in the average 5 per cent, while the nickel content in some samples has reached 12 per cent. Dunite is a brown earthy mineral containing 1.5 to 2 per cent nickel. The general average content of nickel in all ore is about 2 per cent. These are two analyses:



SWITCHBOARD.

Garnierite: 7.3 per cent Ni, 37.5 SiO_2, 29.0 Al, 1.8 Fe, 10.0 Mg, 0.1 CO, 11.9 H_2O.

Dunite: 1.7 per cent Ni, 41.8 SiO_2, 6.7 Al, 8.3 Fe, 28.2 Mg, 0.02 CO, 10.9 H_2O.

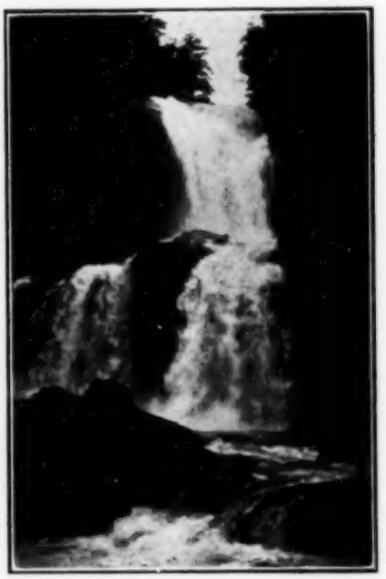


PART OF POWER PLANT.

Both ores contain much muscovite and the brown variety contains some chromite.

Electric Smelting.—Dr. Hennig found that these low-grade nickel ores could be converted into a marketable product by a simple direct reduction process with coke in an electric furnace. On a laboratory scale it was thought necessary to add lime to the charge of ore and coke, but when working on the larger scale at Webster, lime was found to be unnecessary. The ore is crushed, when in large lumps, and then mixed with some 10 per cent of crushed coke to reduce the oxides and silicates.

The product of the electric furnace process is a silicide of nickel and iron containing some chrome, aluminium and magnesium and a small quantity of carbon (probably less than 1 per cent). The metal is extremely brittle and is easily crushed: it has a steel-gray color and a high luster on fresh fracture; the specific gravity is about 6.



ONE OF THE FALLS.

This nickel silicide is directly applicable for making nickel steel. As the nickel silicide is obtained from the ore in a single operation, it will be evidently cheaper than metallic nickel for nickel-steel making. The nickel silicide dissolves easily in molten steel.

The exact composition of the nickel silicide varies with the proportion of the charge and the ore, but the composition can be controlled quite readily. It is, of course, advantageous to produce a number of grades for different purposes.

Nickel silicide containing 10 to 30 per cent Ni, 20 to 30 per cent Si, 40 to 50 per cent Fe, 5 to 10 Al, 3 to 5 Cr, and 3 to 4 C, Mg, S, P can be made. It is proposed to market nickel silicide at 10 cents per pound up according to the nickel content and to make no charge for the other constituents.

The molten slag and metal are tapped into large molds or slag pots, and a clean separation is made due to the difference in specific gravity. It was originally intended to crush the slag and pass it over concentrating tables to recover the finely divided particles of nickel silicide, but it will hardly be necessary to do this on account of the clean separation now being made at Webster. In a small laboratory furnace the heat in the slag was smaller and the slag contained much metal; but with a very hot slag the metal readily sinks to the bottom and the slag is free from metal.

Electric Furnace.—The electric furnace is made of a sheet-steel shell, 5/8 in. thick, 6 ft. in diameter and 5 ft. high, and is bolted on a 3/4-in. plate, which is connected to one pole of the electric circuit. The bottom of the furnace thus serves as one electrode; it is formed of a number of iron rods cast into the baseplate to act as conductors; around these iron rods carbon

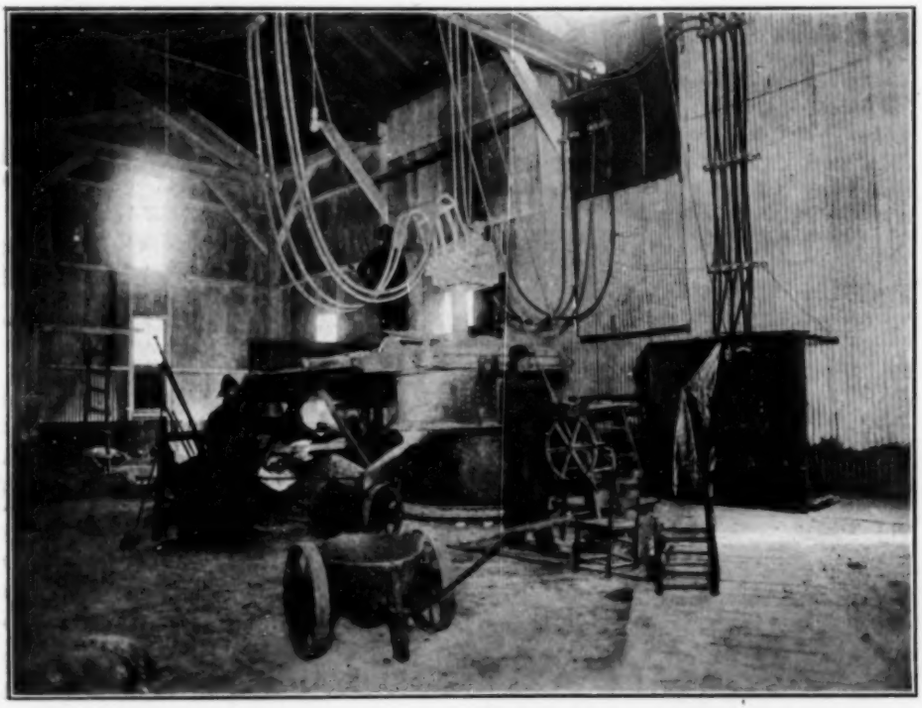
is rammed to form the hearth. The furnace walls are lined with firebrick, so that the inside diameter of the furnace is 4 ft.

The furnace is covered with a cap through which the other electrode, in form of a carbon block or rod, is suspended.

Power Plant.—At present the capacity of the plant is 1000 kw, generated entirely by steam, using wood for fuel. The boiler room, which is situated alongside the mill, contains four 200-hp Wicks return-tubular boilers, furnishing steam for one 1000-hp Hamilton-Corliss engine. This drives four direct-current generators, specially built by the Western Electric Company.

The generators have six poles and are wound to deliver a normal current of 6800 amp at a pressure of 50 volts. They are guaranteed to maintain an overload of 100 per cent for two hours and 150 per cent for 10 seconds without undue heating. As a sudden load of 50,000 amp is liable to occur, all connections, busbars, circuit-breakers, etc., were designed accordingly.

The main circuit-breaker on the furnace switchboard is the largest ever made in the United States, and the switchboard panel itself is made of slate 4 in. thick.



NICKEL SILICIDE ELECTRIC FURNACE.

As has already been mentioned, the electrical energy will be ultimately generated from water-power. Running through the property is the Tuckaseige River, a stream about 100 ft. wide, 2 ft. deep and having a fall of 10 ft. per mile. Two miles from the mine is an excellent dam site, capable of furnishing 2000 hp, and 12 miles away in an air-line is a fall of water from which 6000 hp may be derived. It is proposed to build a dam at the former point, and to install turbines at the latter. Current will be transmitted at a pressure of either 66,000 volts or 110,000 volts, and this will be transformed at the plant.

It is intended not to restrict the manufacture to the production of nickel silicide. By bessemerizing ferro-nickel is to be produced.

Chrome nickel alloys are also to be made, and with ores from another property owned by the company, it is intended to extend the manufacture to all kinds of nickel alloys and metallic nickel.

On the Equilibrium of the System Consisting of Lime, Carbon, Calcium Carbide, and Carbon Monoxide.

BY M. DEKAY THOMPSON.

1. Introduction.

While the author of the following paper was working on the subject indicated in the title above, an article dealing with the same matter appeared in *Electrochemical and Metallurgical Industry*.[1] The present writer's results did not agree with those in the article referred to, and it was, therefore, thought best to publish a preliminary paper on the subject, which was accordingly presented at the October meeting of the American Electrochemical Society in New York. As the work has now been brought to a close, the following article will be made complete, including all of the preliminary publication that is necessary for clearness.

According to the phase rule[2] the substances taking part in the reaction $CaO + 3C \rightleftarrows CaC_2 + CO$ form a monovariant system; that is to say, for any given temperature there is a definite pressure of carbon monoxide which will preserve equilibrium. In order that equilibrium can exist the reaction must be reversible. The fact that this reaction is reversible has been shown by Rothmund[3] and others.[4] Rothmund also attempted to measure the temperature of formation of carbide by heating to different temperatures lime and carbon, and testing the charge immediately afterward to see if it reacted with water, giving off acetylene. The furnace used consisted of a carbon tube through which an electrical current was passed.

The assumption that must be made with regard to the partial pressure of the carbon monoxide is that it is constant and is due to oxygen of the air acting on the carbon tube, giving one-third of an atmosphere.[5] Unless the temperature is raised above that corresponding to one-third of an atmosphere, no carbide would be found. By repeated trials this temperature could be located within certain limits, if the above assumption is true. In this way Rothmund found 1620° C. as the temperature of formation. Similar experiments were repeated later by Rudolphi,[6] who found the temperature of formation to lie between 1800° C. and 1819° C.; that is, about 200° higher than Rothmund's value. The temperature measurements were made by an optical method, as were also Rothmund's. Finally, Lampen,[7] by a method similar to the above, using a Wanner pyrometer temperature measurements, found 1725° C. for the temperature of formation.

It seemed evident, from the poor agreement of these results, all obtained by the same methods, that some other method would have to be used in which the pressure of the carbon monoxide

[1] C. A. Hansen, this journal, 7, 427 (1909).
[2] See Findlay, "The Phase Rule," p. 16.
[3] *Zeitschr. f. anorg. Chem.* 31, 136 (1902).
[4] A. Frank, *Zeitschr. f. angew. Chem.*, 1905, p. 1734.
[5] Rothmund erroneously assumes the pressure of the carbon monoxide to be 1/5 atmosphere, probably because this is the partial pressure of oxygen in the atmosphere. Taking into consideration that every mole of oxygen produces two of carbon monoxide, ⅓ atmosphere is the result obtained.
[6] *Zeitschr. f. anorg. Chem.* 54, 170 (1907).
[7] *Jour. Am. Chem. Soc.* 28, 864 (1906).

could also be measured, as these differences might be due simply to different values of this quantity. It was the object of the following investigation to make these measurements.

2. Method and Results.

The method decided on was to heat the charge in a vacuum furnace connected with a mercury manometer and to measure the temperature of the charge and pressure of the carbon monoxide when equilibrium is reached. A small Arsem[8] vacuum

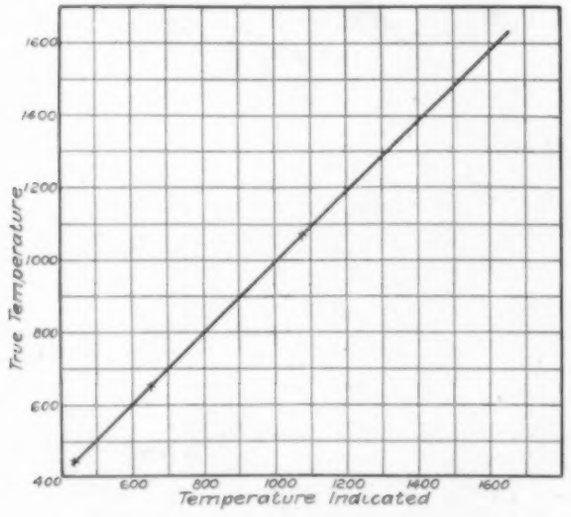


FIG. 1.—CALIBRATION OF THERMOELECTRIC JUNCTION.

furnace, made by the General Electric Company, was the apparatus used. It consists of a cylindrical bronze casting 24 cm inside diameter and 39 cm in length. Parallel to the axis in the center of the casting, and fastened to the lid, is a graphite helix, 27 cm in length, 5.1 in. outside diameter and 0.5 in. thickness of wall. The helix is clamped at each end by water-cooled electrodes. The lid is fastened to the casting with a number of cap-screws and a lead washer.

The whole furnace is immersed in water with the exception of a tower projecting from the center of the lid containing a mica window, making it possible to see the hot material held in the center of the spiral. The support for the crucible is a graphite rod held by the lower electrode, but insulated by lava rings. The lid also contains a pipe by which the furnace may be exhausted. A Geryk oil pump was used for obtaining the vacuum. The pressure could be read by a wooden scale divided in millimeters on a mercury gage completely evacuated and sealed off at one end, thus making a siphon barometer.

The temperature of the gas contained in the furnace is not constant, but all that determines the equilibrium besides the pressure, is the temperature of the solid substances and of the gas in contact with it. Of course, the pressure must be constant throughout the furnace.

In the first experiments the temperature was measured by a Wanner pyrometer, which rendered it necessary to replace the mica window by one of glass clamped between rubber and sealed up with paraffin. In calibrating the pyrometer a similar piece of glass was placed between the amylacetate standard and the instrument. The Wanner was found to be unreliable, however, apparently due to inconstancy in the amylacetate standard.[9]

The furnace was, therefore, calibrated by means of a platinum platinum-rhodium junction—that is, the temperature of the crucible was measured while the power was held constant. The temperature was then subsequently determined by measuring the power applied. Heating was furnished by alternating current with a frequency of 60 cycles per second. This was taken from a transformer switchboard so arranged that the voltage could be varied in steps of about 12 volts. For the finer regulation a carbon-plate rheostat, in which current regulation could be obtained by varying the compression on the plates, was found satisfactory. The terminals were copper boxes filled with water.

Fig. 1 gives the calibration of the junction. The galvanometer was a Siemens & Halske instrument made for this special purpose, but which did not read as high as the melting point of platinum.

TABLE I.—CALIBRATION OF THERMOELECTRIC JUNCTION.

	True temperature.	Temperature read directly from scale.
Melting point of gold.....	1065° C.	1075° C.
Melting point of aluminium..	655° C.	650° C.
Boiling sulphur	445° C.	440° C.

In Table 2 and Fig. 2 the calibration of the furnace is given. The power was obtained from voltmeter and ammeter readings. The ammeter scale read to 5 amp and was connected to a current transformer with a ratio of 60 to 1. This instrument was not calibrated. Two voltmeters with scales from 0-65 and 40 to 160 were used. These were calibrated so as to make them comparable with each other. The alternating-current instruments were of the Thomson type made by the General Electric Company.

In calibrating the furnace the wires of the pyrometer were protected by fused silica tubes, which extended up into the tower in the lid of the furnace. The tubes were covered at the junction by a short graphite tube. This projected through a hole in the cap of the crucible containing the charge and rested in the charge. The bare wires were brought out of the furnace

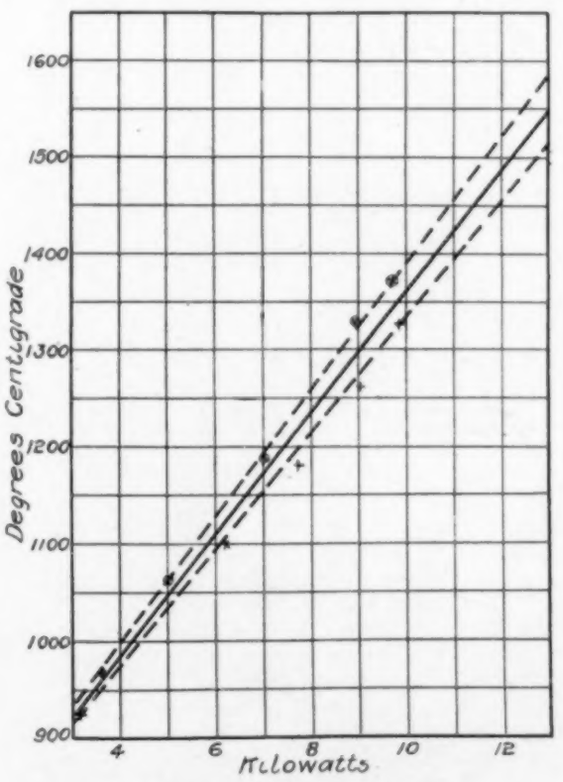


FIG. 2.—CALIBRATION OF FURNACE.

at the top of the tower between rubber washers; the furnace was then evacuated and the calibration taken.

The carbon shield surrounding the spiral was not used in these experiments on account of the fact that carbon absorbs a large amount of gas, which is not easily removed. It will be evident from the method of experimenting described below that its use would not be permissible.

[8] *Trans.* Am. Electrochem. Soc. 9, 163 (1906).

[9] The temperatures measured in the former article on this subject are accordingly from 100° to 150° too low, but the general conclusions there reached are not affected.

TABLE 2.—CALIBRATION OF FURNACE.

Kilowatts.	Temperature by thermo-electric junction.	Remarks.
3.60	968°	
7.03	1185°	
8.98	1325°	First spiral.
9.71	1368°	
3.12	925°	
4.99	1062°	
7.10	1180°	Second spiral.
8.03	1225°	
9.00	1262°	
9.81	1325°	Second spiral
7.68	1180°	repeated on
6.15	1100°	following day.

In Fig. 2 a circle is put around those points taken with the first spiral. It is evident from this diagram that this method of obtaining the temperature is not as accurate as the Wanner pyrometer would be were it in good condition.

It will be seen that there is no regular difference in the calibration of the two spirals, except that all the points of the first coil lie on the upper dotted line, while some of the points for the second coil lie on the upper as well as the lower. This is probably due to the fact that the second spiral was calibrated more than once. It was thought best under the circumstances to draw the solid line midway between the two extremes and take this for estimating the temperature.

A further test was made to see how constant the temperature was throughout the length of the crucible. For this purpose the junction, protected by silica tubes, was lowered through the window in the tower into the crucibles and the furnace heated without pumping out the air. There was no lid on the crucible in this experiment. The results are given in Table 3.

TABLE 3.—VARIATION OF TEMPERATURE IN CRUCIBLE.

Distance of junction from bottom of crucible.	Temperature.
0.0 cm.	1220°
0.6 cm.	1220°
1.8 cm.	1225°
3.3 cm.	1225°
4.0 cm.	1220°
4.4 cm.	1215°
4.8 cm.	1205°

The power was 8.36 kw.

It is seen that without the lid and with no charge in the crucible the temperature is quite constant, which would be improved, if anything, when the charge is in the crucible and the lid in position.

The carbide used in the following experiments was made from Merck's lime and Acheson graphite powder in the form of turnings from graphite electrodes. Carbide was made by heating a mixture of the two in an arc furnace consisting of a graphite electrode and graphite crucible. By the loss-in-weight method[10] it analyzed 78 per cent pure. The impurities must have been carbon and lime, which were not harmful for these experiments.

The first experiments were carried out at from 1700° to 2000°, but no consistent results could be obtained. After a run at these temperatures it was found that the walls of the furnace were always lined with a white powder, whether lime and carbon were heated alone or when carbide was in an atmosphere of carbon monoxide. It was found when carbide was heated in carbon monoxide to about 1800° only graphite was left in the crucible and the white powder was formed on the walls. When carbide was heated alone in a vacuum the walls of the furnace were lined with a thin sheet of calcium, which easily peeled off and took fire when brought in contact with moisture. Graphite was left behind in the crucible. These two facts taken together show that calcium reduces carbon monoxide according to the equation:

$$Ca + CO = CaO + C.$$

Therefore, if carbide is to be produced, it must either be below the temperature where it breaks up into its elements or the velocity of the reaction

$$CaO + 3\,C = CaC_2 + CO$$

must be greater than the velocity of the preceding reaction. The latter is evidently the state of affairs in the manufacture of carbide, but equilibrium measurements could hardly be made under this condition.

From a number of experiments, which it is not necessary to reproduce here, it seemed that 1500° C. was about the highest temperature at which equilibrium could be measured. This conclusion was based on the quantity of white powder found on the walls of the furnace after runs at different temperatures. Some further experiments at about this temperature showed that it would be impossible to differentiate between the pressure of carbon monoxide and occluded gases that came out of the carbon spiral and the charge on heating in a vacuum.

It was therefore decided to heat the charge in some indifferent gas, which could be drawn off and analyzed for the amount of carbon monoxide present. Hydrogen was, of course, the only gas available. Nitrogen could not be used on account of the fact that it is absorbed by calcium carbide, forming calcium-cyanamide. Hydrogen would have no action on carbide,[11] but it does enter into an equilibrium with carbon monoxide according to the reaction

$$H_2O + C \rightleftarrows H_2 + CO$$

which is the reaction of water-gas formation. If an appreciable quantity of water were produced from hydrogen and carbon monoxide this would react with the carbide and form acetylene and in analyzing for carbon monoxide by absorption in cuprous chloride solution, acetylene would be mistaken for the former. It can be shown, however, that the quantity of water vapor formed is too small to have any effect. The free energy of this reaction is given by the equation[12]

$$\Delta F = -27{,}950 + 31.76\,T + 4.58\,T \log \frac{p_{H_2O}}{p_{CO}\,p_{H_2}}$$

where T is the absolute temperature and the p's are partial pressures. At equilibrium $\Delta F = 0$, therefore, placing the right-hand side of the equation equal to zero, and substituting for T its value 1773° absolute, we find that for 1500° C.

$$\frac{p_{H_2O}}{p_{CO}\,p_{H_2}} = 0.000324$$

If p_{H_2} equals about 90 cm of mercury, as it does in the following experiments:

$$\frac{p_{H_2O}}{p_{CO}} = 0.0029$$

or $p_{H_2O} = 0.003\ p_{CO}$, which is a negligible quantity. The temperature of the gas, however, is not all at 1500°, but falls off to the temperature of the water-cooled walls of the furnace. At 1000° C. $p_{H_2O} = 0.063\ p_{CO}$ which is still a relatively small amount. What actually happens is that at the higher temperatures where the velocity of the reaction is great, the equilibrium varies uniformly with the temperature, but as the gas reaches the cooler portions of the furnace, due to convection currents, it suddenly becomes chilled to a point where the reaction practically stops, leaving the concentrations at values corresponding to the higher temperatures.

(To be concluded.)

Mme. Curie has announced the isolation of an appreciable quantity of the rare element polonium. It is more energetically radiactive than radium. The element was extracted from pitch blende and one-half of the quantity isolated disappeared by disintegration in 140 days.

[10] Lunge, Chemisch-technische Untersuchungs Methoden, 5te Auflage, Band II, 711. The drying tube contained a layer of P_2O_5 besides one of $CaCl_2$, which the escaping gas had to pass first.

[11] Moisson, "The Electric Furnace," p. 211.

[12] Bodländer, *Zeitschr. f. Electrochem.* 8, 833 (1902).

Notes on Chemistry and Metallurgy in Great Britain.

(From Our London Correspondent.)

Compression of Fluid Steel.

At a recent meeting of the Sheffield Society of Engineers and Metallurgists, Mr. G. Rodger gave a lecture on "Fluid Pressed Ingots," illustrated with demonstrations of the pressure method of preventing "piping."

The lecturer described the methods adopted for preventing the formation of hollow spaces caused by the contraction of the steel when solidifying. Slow running, feeding with melted steel and the application of feeding heads, were methods generally adopted, but there was still some waste, and every ingot had to be topped, causing a loss of from 10 to 30 per cent. The pressure process provided an effective remedy. It consisted in using moulds, which enabled pressure to be brought to bear upon two opposite sides of the ingot as soon as it was sufficiently set to stand the removal of the distance pieces. The pressure was gradually increased until the ingot was able to bear the maximum pressure intended. He exhibited a wooden model, lent by Messrs. Davy Brothers, of a large press exerting a pressure of about 10,000 tons, and also a drawing of a smaller press capable of dealing with ingots from 200 lb. to 800 lb. The two machines for carrying out the process had been in regular and satisfactory use at Brightside Works for nearly six years. One was capable of dealing with ingots of 30 tons.

In connection with the same subject Von Paravicini states (*Stahl und Eisen*) that strewing cold sand, etc., on the tops of ingots after pouring, in order to check the formation of cavities due to the sudden cooling of the metal against the wall of the mould is not effectual, even when fuel is added at the same time. As a more efficient method he uses a crucible, the bottom half of which has been filled with finely broken coke and the upper half with sand. This is kept as hot as possible in a suitable heating furnace, and as soon as pouring is finished is inverted over the top of the mould, so that the hot sand comes in contact with the metal and is itself covered by the coke. This forms a heat store; the sand prevents the metal being carbonized by the coke, and at the same time helps the metal to retain its own heat. Consequently the solidifying surface of the metal is protected from further cooling, and the weight of the inverted crucible and its contents exerts considerable pressure on the molten steel. The weight of the waste head on ingots and castings is reduced by as much as 40 per cent.

Atmospheric Nitrogen Products.

Professor Crossley has drawn attention to the absence of enterprise in Great Britain in the electrical production of nitrates and other nitrogen compounds from the atmosphere. He pointed out that on the Continent there are many factories for these purposes, whilst in England practically nothing has been done. Not only will these nitrogen compounds be required to supplement or replace the natural nitrates now used as fertilizers—the supply of which cannot be indefinitely prolonged—but atmospheric nitrogen may also under certain circumstances become the only possible source of adequate supply for the manufacture of sufficient nitric acid to meet the requirements of our manufacturers of nitro-explosives, and various chemical products. The question is really serious; and it is to be hoped that the apathy with which it has hitherto been regarded here may soon give place to practical and energetic action.

The Le Chatelier Test for Cement.

At the last (March) meeting of the Concrete Institute Mr. D. B. Butler read a paper on "The Le Chatelier Boiling Test of Portland Cement." After favorably noticing the Bauschinger micrometer-calliper apparatus, he said the only other quantitative method of note for determining expansion was that devised by M. Le Chatelier, which was adopted by the British Standards Committee in 1904 as the standard method. This test had an advantage over the Bauschinger apparatus in that it was cheap and simple, and involved no costly apparatus; but whether it was equally accurate, was quite open to discussion. He had carried out many thousands of tests for soundness by the Le Chatelier method, and the conflicting results he had sometimes obtained had led him to the conclusion that where the condemnation of a cement for unsoundness was concerned, the results given by the Le Chatelier test should not be too rigidly interpreted. It was quite an open question whether a cement should be condemned as unsound because it would not withstand boiling water 24 hours after gauging, whether that 24 hours' preliminary hardening was in cold water or in air.

Considerably less than 20 years ago not 10 per cent of the Portland cement manufactured in England or elsewhere would stand the Le Chatelier test. Was, therefore, 90 per cent of the cement used 20 years ago unsound? This, in view of the hundreds of thousands of tons then used for important engineering work throughout the world, was rather a startling proposition; and having regard to the excellent condition of such work at the present time, was one that could scarcely be seriously maintained. Mr. Butler, in alluding to the present good state of cement work executed long ago, does not appear to have made allowance for the improvement which unquestionably occurs with age. Surely his allusion to the "mass of anomalies and conflicting results continually met with" (in the Chatelier test) is an unintentional exaggeration. At all events such unhappy results are rarely, if ever, obtained by those who adhere rigidly to uniform manipulative detail.

Electric Furnace Steel.

At the meeting of the Sheffield Society of Engineers and Metallurgists early in March, Mr. Gerald Hooghwinkel predicted that in the near future nearly all the steel required would be of special qualities containing some of the rare metals. Almost all these steels had been manufactured in the electric furnace in various countries, and before long no steel works would be complete without electric furnaces to supply at reasonable prices the ever-growing demand for special steels made to stringent specifications. The greatest demand would arise when the railway authorities had settled upon a new rail for main lines; for the present rails were quite unsuitable to stand for any great length of time the strains to which they were submitted. The German State Railway authorities had issued a specification for electric steel rails specifying a tensile strength of 99,000 lb. per square inch, against 85,000 lb. per square inch for basic rails, with a guaranteed life of ten years for track rails. The cost of the electric power was only a small fraction of the total cost of production, about 3 per cent to 8 per cent for hot and cold charges respectively. With a supply at a price between 1 cent and 2 cents per kw-hour the production of electric steel was economical, but the waste gases from blast furnaces and coke ovens were available for profitable power generation on a large scale.

The electrical production of steel castings both for high-grade and medium-grade products would replace the crucible method, to which it was obviously much superior; moreover, the high temperature of the cast could be utilized in manufacturing complicated parts. The total cost of production of steel castings in a one-ton Stassano furnace at the Bonn File Works was $45 per ton as against $75 to $100 per ton for crucible furnace steel. The difference was partly due to the cheaper materials, etc., whilst working costs were $16 less than for the crucible furnace. A certain quality of steel was being made in the United States for $90 a ton which commanded a much higher price in Sheffield.

Corrosion of Steel in Reinforced Concrete.

E. R. Matthews has found that a complete preliminary coating of cement effectually prevents corrosion provided that such coating be allowed to dry thoroughly before encasing with concrete having a porous aggregate. When a non-porous aggregate is employed the preparatory coating of cement is

not necessary. For work exposed to air and water broken stone and hard brick were found to be the best material; whilst porous substances like coke-breeze and slag are not suitable. Where water-tightness is required river sand should not be used in reinforced concrete. Rusted steel embedded in concrete was found to become brighter, even after exposure to water. Linseed oil, turpentine and similar preservatives would probably promote rather than prevent corrosion.

Ferrosilicon.

The recent Local Government Board's report on ferrosilicon perils (see March issue of this journal, p. 133) has evoked from R. Taussig the statement that in furnaces of high power the ferrosilicon now produced is practically pure and contains only minute quantities of arsenides and phosphides. Its quality is demonstrated by its stability on exposure to the atmosphere; and if storage in a moist atmosphere does not result in decomposition, the ferrosilicon will not have any tendency to evolve explosive or poisonous gases. Yet it is proposed in the report to exclude from the market such grades which contain approximately 50 per cent of silicon. Where ferrosilicon is produced in large furnaces the silicon content does not affect the passing of the arsenic and phosphorus into the slag; but in the small furnaces generally employed this refining does not occur.

Estimation of Water in Petroleum.

A rapid method of determining the amount of water in petroleum residues used for fuel, devised by Messrs. R. W. Roberts and A. Fraser, consists in adding calcium carbide and measuring the evolved acetylene. Tests were carried out (a) by taking two equal quantities of the oil, adding a weighed amount of water to one, acting on both with carbide and noting the difference between the volumes of acetylene produced; and (b) by adding excess of carbide to the oil until evolution of gas ceased, then running in a weighed quantity of water, and again measuring the acetylene given off. The average yield of gas, at 0° C. and 760 mm was 580 c.c. per gramme of water, which agrees closely with Dupré's results in his experiments on the estimation of moisture in cordite. The generating flask must be kept cool to avoid evolution of gaseous hydrocarbons from the oil. The acetylene is passed into a saturated solution of sodium chloride, also saturated with acetylene, contained in a jar furnished with an outlet tube, through which the volume of salt solution displaced by the gas passes into a suitably graduated jar.

Accumulators in the Tropics.

Mr. E. P. Harrison, of the Physical Laboratory, Presidency College, Calcutta, states, in a recent issue of *Nature*, that the difficulty experienced in hot countries in keeping small accumulators in working order is probably due to the cells being filled with dilute acid of density 1.190 at a temperature of 30° or 35° C. While this is a proper density to use in a climate where the temperature is 15° to 20°C., corresponding to a 20 per cent mixture, it is too high for a hot climate, where it really represents a 23 per cent mixture; a density of 1.170 or even 1.150 is more suitable in hot climates.

Turbine Drums.

A new method of manufacturing turbine drums for marine propulsion has just been adopted by Messrs. John Brown & Company, who have substituted a special type of rolling mill for the process of hollow forging with the hydraulic press. The mill will roll steel cylinders up to 15 ft. diameter, a length of 10 ft., and 30 tons weight. The firm is now making drums for the two great White Star liners being built by Messrs. Harlan & Wolff. These drums will be 12 ft. 2½ in. in diameter, 7 ft. 8 in. in length, and 24 tons in weight.

High-Pressure Gas Furnaces.

Mr. A. W. Onslow recently presented to the Society of Chemical Industry a description of arrangements of furnaces and injector burners in which constant and easily reproduced temperatures up to 2600° Fahr. can be obtained by the use of gas at carefully regulated pressures, varying from 100 in. of water downwards. The system is applicable to glass-making, lead smelting either by direct heat or by radiation, and to the tempering of axle trees and long steel bars. Large combustion chambers were not necessary with high-pressure gas; and by confining action of the air and gas to the object to be heated the consumption of gas can be reduced two-thirds. He referred to the use of high-pressure gas for the economical warming of buildings as carried out under Colonel Baynold's superintendence at the Royal Arsenal. These improvements gave better heating results at a lower cost as a consequence of the use of smaller combustion chambers and the simplification of apparatus.

Analytical Notes.

At a meeting of the London section of the Society of Chemical Industry early in March "The Rational Analysis of Clays" was the subject of a paper by Mr. W. C. Hancock, who said that the ultimate analysis of a clay showed the total amounts of the acid and basic oxides present, whereas the "rational" or "proximate" analysis was really a mineralogical separation of the constituents of clay into three species, viz., aluminous substance, quartz and felspar. Certain inferences could be drawn from each and served as guides in the employment of the clay. Examination of the portions soluble in acid and in alkali and of the insoluble residue, and comparison of the results with the ultimate analysis would enable the extent and limitations of the process to be judged. To obtain comparable results, standardization of method was necessary.

At a recent meeting of the Society of Public Analysts, Mr. E. R. Andrews, in a "Note on the Analysis of Ultramarine Blue," described a method of effecting its decomposition by agitation of the pigment with saturated bromine water. The result was that practically all the products of decomposition remained in solution. After removal of the silica the alumina, sodium, etc., might be determined in one portion of the filtrate; and the sulphur in another by direct precipitation with barium chloride.

A "Note on the Kjeldahl Estimation of Nitrogen in Fatty Substances," by Mr. J. A. Brown, suggested that to prevent the frothing which sometimes occurs in distilling off the ammonia when determining nitrogen in fatty substances, the acid contents of the flask should be diluted with about 100 c.c. of water, and that 50 c.c. of this should be boiled away before making alkaline and distilling.

Market Prices, March, 1910.

Copper: rose from the 1st (£59 10 s) to £60 10s. on the 3d; thence fell until on the 11th it touched £59. Since then flat and not inclined to alter, closing at £58 15s.

Tin: rose from £148 to £150 in the first three days; dropped rapidly to £143 during the next fortnight, and thence recovered to £144, closing at £146 15s.

English lead has been steady with slight downward tendency; opened £13 12s., closed £13 2s 6d.

Iron, Hematite: Has risen steadily since the 3d, opening 64/3, it closes at 66/-.

Scotch Pig: Has had an upward tendency, starting at 57/4, it closes at 57/6.

India Rubber, Para fine: Has risen throughout the month in a sensational manner. On March 2 it was 8/10½ per lb., on the 9th, 10/1; it closes at 10/5. During the week ending March 26th, smoked sheet reached the record price of 11/0¼. As a result, new companies are incessantly floated. It is probable that present prices are inflated, but, as sudden increase of supply is practically impossible, it is difficult to see how any considerable reduction can occur.

	£	s.	d.
Aluminium ingots	75	0	0
Alumina, Alum, lump, loose, per ton	5	12	6
Antimony Black Sulphide Powder	20	0	0
Borax, British Refined Crystal	16	0	0
Sulphate of Ammonia, f.o.b. Liverpool, per ton	12	10	0
Sal-Ammoniac, firsts, delivered U. K., per ton	42	0	0

Copper Sulphate, per ton	18	15	0
Camphor, 1-oz. tablets		1	7
Caustic Soda, 48 per cent ord., per ton	5	10	0
Bleaching Powder, 35 per cent	4	5	0
Shellac, standard T. N. Orange Spots, per cwt.	3	10	0
Sulphur, recovered, per ton	5	0	0
Carbolic Acid, liquid, 97/99 per cent per gal		1	0
Hydrochloric Acid, per cwt		5	0
Creosote, ordinary good liquid, per gal			2¼
Naphtha, solvent 90 per cent at 160°C., per gal		1	3½
Platinum, per oz., nominal	5	15	0
Copper Ore, 10 to 25 per cent per unit	9s 9d to 10s 3d		
Tin ore, 70 per cent, ton	£90 to £92		
Mica, small slab, in original cases, per lb.	6d to 1/-		

Note.—Of the chemicals it will be noted that with the exception of ammonia and copper sulphate, bleaching powder and shellac (all lower) and naphtha solvent (slight increase) the prices remain firm.

Synopsis of Metallurgical and Chemical Literature

Iron and Steel.

Special Steels; Nitrogen in Steel; Case Hardening.—Vol. I of the *Iron and Steel Institute Carnegie Scholarship Memoirs* (pages 1 to 59), contains a paper by Mr. Walter Giesen on "the special steels in theory and practice." The influence of nitrogen on steel is first emphasized. In the case of mild iron the tensile strength increases with the nitrogen content, while the elongation diminishes. At a critical nitrogen content, which is between 0.037 per cent and 0.041 per cent, the elongation disappears entirely and the steel becomes quite brittle. In the course of a number of examinations of ordinary steels, the author has found the critical limit to be 0.039 per cent of nitrogen, but this critical nitrogen content depends largely on the percentage of carbon in the steel. The author urges that in steel specifications the proportion of nitrogen should be expressly limited to a certain maximum; this is especially important for special steels. Vanadium is recommended to remove both nitrogen and oxygen from steel. The case-hardening of special steel is then discussed and it is emphasized that all parts that are to be hardened and tempered should be made of steel with a low content of carbon and nickel; while chromium steel should be used for bearings, silicon steel for springs and gear, and chromium-vanadium steel for all parts that will be subjected to considerable vibration, and at the same time are required to be hard. The author describes a reliable furnace for case-hardening. A good and cheap cementing medium is composed of 60 parts of ivory black (eborustum), 35 parts of leather-charcoal powder (free from extraneous admixtures), 3 parts of potassium ferro-cyanide ($Fe(CY)_6K_4 + 3\,H_2O$), and 2 parts of copper sulphate ($CuSO_4$, $5\,H_2O$), or saltpeter (KNO_3). Carbon and barium carbonate in the proportion 3.2:1 ($8\,OC + 25\,BaCO_3$); 1.7:1 ($59.5\,C + 35\,BaCO_3$); or 1:1.7 ($35\,C + 59.5\,BaCO_3$), also furnish an extremely good cementing powder. Cyanides, too, have a carburizing action at high temperatures, but with these media the crucible must not be filled too full. The results are given of the case-hardening of various special steels. The author then gives a long account of a metallographical, microscopical, and micrographical examination of various special steels and their mechanical and physical properties (nickel-chromium steels, nickel steels, chromium steels, manganese steels, tungsten steels, titanium steels). The general conclusion as to the microstructure of these steels are summed up and a theory of the ferro-carbon alloys and high-speed cutting steels is given, also of the thermal and mechanical treatment of ordinary carbon steels. (High-speed steels; structural steels; structural changes in superheated steel; state of equilibrium of the "iron-carbon" systems; alternating stresses; phenomena of hardening.)

Nickel-Steel Riveted Joints; Slip; Corrosion.—Nickel steel was used for the rivets of the Manhattan and Blackwell Island Bridge because of its great strength and other excellent qualities. It was used without extensive tests being made of the strength and other properties of joints riveted with nickel-steel rivets. For this reason an investigation by Dr. E. Preuss on the strength of nickel-steel riveted joints, with special reference to resistance to slip, is of especial interest (*Iron and Steel Institute Carnegie Scholarship Memoirs*, Vol. I, pages 60 to 142). Ninety-three nickel-steel riveted joints of all kinds (made from four different kinds of commercial nickel-steel, delivered from stock) were tested. The rivet heads were of the shape generally used either in boiler-making or in bridge construction, according to whether the rivets were delivered by boiler makers or bridge builders. The tests lead to the following conclusions: The strength of nickel-steel riveted joints is about two to two and a quarter times as high as that of joints riveted with wrought-iron or mild-steel rivets. The advantages thus gained are self-evident. For instance, the nodal points in bridge construction are easier to make. As fewer rivets are used, the expenses for rivet material and for making the holes and making the rivets are reduced; while, as rivets of smaller diameter are used, the riveted plates or other parts are less weakened, so that they need not be so broad as they usually are. Though the price of nickel-steel is slightly higher than that of other rivet material, this is of no great importance in comparison to the advantage above mentioned; indeed, the higher price of nickel-steel is balanced by the smaller amount of the material used. Of the nickel-steel tested only that made in the electric furnace was too brittle to be used. It has an exceedingly high ultimate shearing strength, but this was of little use, as, especially in lap joints, the brittleness of the nickel-steel caused the rivet heads to break off before the ultimate shearing strength of the rivet shank had been reached. The remaining three kinds of nickel-steel were extraordinarily tough, and of the large number of rivets made of these only one rivet head was broken off, and in this case the rivet was most probably overheated.

With regard to slipping of the plates of a joint, the results of these tests have led the author to other conclusions than those formed by von Bach. The author, who measured the amount of slip with a mirror-reading apparatus, capable of measuring a slip of 1/5000 mm, found that for nickel-steel riveted joints the slip began asymptotically at loads much smaller than the working load of the riveted joint, whereas von Bach found that no slip took place up to a certain load, but that the plates slipped suddenly when the load was increased by about 1000 kg. In the author's opinion riveted joints should be so designed that the resistance to shearing alone is taken into consideration, as is generally the case. With regard to slip, nickel-steel and wrought-iron rivets were found to be equally efficacious. The slipping of butt joints was greater than that of lap joints of the same ultimate breaking strength. In view of the high shearing resistance of nickel-steel it seems advisable to choose, for a given thickness of plate, a rivet with a shank of smaller diameter than is taken for wrought-iron or mild-steel rivets. As nickel-steel is stronger and harder than the rivet material hitherto used, it requires a greater amount of work (something like 25 per cent greater pressure) to form it into rivet heads.

Some interesting observations were made on corrosion in sea water. According to the electrolytic theory of corrosion the electric potential between the rivets and the plates to be joined together should not be too high in order that the materials should not suffer corrosion by electrolysis. To determine the

influence of electrolytic action six nickel-steel rivets and six wrought-iron rivets were riveted into two mild-steel plates, which were then left for two months in salt water without any protective coating. The percentage of salt in the water was about that of sea water, namely, 3.6 per cent. The following reductions in weight took place in the two months during which the tests lasted:

Material.	Weight of beginning of test. Grams.	Loss of weight during test. Grams.
Mild-steel plate with nickel-steel rivets.....	2567	11
Mild-steel plate with wrought-iron rivets....	2794	6

The electric potential between mild steel and wrought iron and between mild steel and nickel-steel was directly measured, and it was found that the electric potential between nickel-steel and mild steel is higher than that between wrought iron and mild steel when submerged in the liquids used.

Gases Occluded in Steel.—In the *Iron and Steel Institute Carnegie Scholarship Memoirs*, Vol. I, pages 219 to 229, Mr. THOMAS BAKER reports on an investigation of the gases given off from steel when heated in vacuo in an electrically heated glazed-porcelain tube. The experiments were made with steel as cast and not with steel which had been subjected to further treatment, such as reheating or rolling—processes which may bring about changes both in the quantity and the nature of the gases occluded. Hydrogen and carbon monoxide form the major portion of the gases evolved on heating in vacuo; carbon dioxide and nitrogen only amounting to 2 per cent or 3 per cent of the total. An actual analysis of the gases drawn off from a piece of steel free from blowholes, when heated for 36 hours at a temperature of 1000° C. is as follows: CO_2, 0.48 per cent; H_2, 49.62 per cent; CO, 48.05 per cent; CH_4, 0.40 per cent; N_2, 1.45 per cent; the small amount of nitrogen present is rather unexpected, but repeated tests on the steels experimented on by the author have resulted in no increase of the percentage above mentioned. The presence of methane is unusual and is to some extent accounted for by the gases given off from the porcelain tubes employed.

In the experiments on sound steel it was found that hydrogen was given off at as low a temperature as 300° C., the rate of evolution reaching a slight maximum at 600° C., and then gradually falling off until a temperature of 900° C. is reached, when it again slowly rises with the temperature; this gas comprises over 90 per cent of the total gas evolved up to a temperature of 500° C. At this point carbon monoxide begins to be given off; its rate of evolution gradually increases until a temperature of 690° C. is reached, when it is so great as to cause a well-marked maximum. After passing 690° C. the evolution falls off and reaches a minimum at 800° C.; it then gradually increases with the rise in temperature, as in the case of hydrogen. At temperatures higher than 760° C. the gases given off consist of almost equal quantities of hydrogen and carbon monoxide. The total volume of gas given off amounted to 91.86 cu. cm, equal to 10.4 times the volume of the steel employed. Similar changes were observed in the gases given off from unsound steel. The total volume of gas given off amounted to 42.09 cu. cm, equal to 5.2 times the volume of the steel. The influence of aluminium in preventing blowholes seems to be due to the fact that it prevents the liberation of gas during the period of solidification and not to any action it may have in hindering the production of carbon monoxide.

Ferromanganese.—Ferromanganese can be produced from ore only by means of a reagent having a greater affinity for oxygen than manganese has, or for which manganese has a greater affinity than oxygen. Only aluminium and carbon have been proved available for this purpose. By means of the aluminothermic carbon-free ferromanganese is being produced commercially, but is naturally high in price. Mr. E. A. WRAIGHT has studied in detail other possibilities of making carbon-free ferromanganese. (*Iron and Steel Institute, Carnegie Scholarship Memoirs*, Vol. I, pages 143 to 160.) His first research relates to possibilities of decarburizing ordinary ferromanganese reduced from the ore by means of carbon and containing carbon. The following decarburizing agents were tried, either in fusion or cementation, or both: oxides, viz., manganese dioxide or pyrolusite, ferric oxide (hæmatite), silica, barium peroxide, alumina, zinc and copper oxides, lime, magnesia and titanic oxide, also ferrous and manganous carbonates (for FeO and MnO); the gases hydrogen, oxygen, and carbon dioxide; and the metals calcium and aluminium. Most of these failed to give any satisfactory reduction of the carbon content of the alloy, and even when the carbon was lowered the process was in no case commercially practicable. While the results were, therefore, entirely negative, one special observation should be mentioned, namely, that proof that at temperatures of 1300° C., 1400° C., and 1600° C. to 1700° C. manganese is not volatile, contrary to the statement of others.

A second series of experiments was made with a view of producing from the ore directly pure manganese free from carbon. First, manganese oxide was intimately mixed with such reducing agents as flour, sugar or starch, and the reduction carried out in a closed iron tube at a red heat. When ferromanganese was produced it was not free from carbon. Gaseous reduction of the ore was then tried, with carbon monoxide or coal gas or hydrogen as reducing agent, without the desired success. Attempts of substituting metals, for instance, calcium, to produce pure manganese from a mixture of manganese dioxide and calcium also proved futile. The final conclusion of the author is that the commercial and economical production of the carbon-free alloy is an impossibility. This failure may be attributed to several facts which have been definitely proved:

1. Manganese has a greater affinity for carbon than for any other element. Evidence of this is shown in almost every experiment that has been made. The only elements that can replace carbon have been shown to be aluminium and silicon. The use of the former entails heavy expense, and produces an alloy which very rapidly disintegrates; further, only about one part of carbon is removed by the addition of 10 parts of aluminium. Silicon, although it replaces carbon to a certain extent, nevertheless soon reaches a limit beyond which it is impossible to further lower the carbon content without enormously increasing the percentage of silicon, in which case a high-grade silico-spiegel is produced instead of carbon-free ferromanganese.

2. Garrison's statement that "in the reduction of manganese ore by carbon, carbide and not the metal is invariably produced," is supported by the results of coal-gas reduction of the ore, but this fact requires modification unless it is assumed that carbides other than Mn_3C exist. This appears to be quite a probable view.

3. Under oxidizing conditions carbon is only removed from the alloy at the expense of manganese. When oxygen, either in the form of air or as oxides, has been tried for decarburizing, manganese has been invariably oxidized, and, although carbon has been to some extent removed, this loss is out of the proportion to the manganese lost.

Gold and Silver

Agitating Cyanide Pulp.—The use of a false bottom of "silica sponge" in a cyanide tank is the new feature of an agitating and filtering device described in a paper read at the March, 1910, meeting of the Amer. Inst. Min. Eng. by E. G. SPILSBURY. The object of the bottom of silica sponge is to provide a medium through which air may be forced to agitate a pulp of ore and cyanide solution. The bottom is raised 4 in. above the tank bottom, thus forming an air chamber into which air is pumped. Air under a low pressure is forced upward through the porous diaphragm at the same time that the charge of pulp to be agitated is introduced above the diaphragm. The entire charge immediately becomes a seething mass, and on account of the fine division of the air as it comes through the diaphragm there are no direct currents anywhere visible. As

each particle of air is released after its passage through the silica sponge diaphragm, it is not subject to further pressure and merely seeks its way to the surface. As the depth of charge increases in the tank, the air pressure is increased to a point just sufficient to force the air through the head of pulp. The results obtained by the perfect mixing and agitation which follows are noteworthy. Extractions of 60 to 75 per cent are obtained in two hours, and an extraction of 99 per cent of the gold and 90 to 95 per cent of the silver is effected in 10 to 12 hours. The low consumption of cyanide is also an important feature of the process.

The silica sponge diaphragm has been found to be an excellent filter for slime pulp, although at first glance it might be regarded as a poor medium, likely to clog in a short time. A year's testing has shown that in the filtration of fine slime pulp, the cake forms promptly on the surface of the filter and does not penetrate and clog the interior. The filter now being prepared for the market has a capacity of 75 gallons of water per square foot of surface per hour under a pressure of 1 ft. head. The formation of a horizontal cake offers an opportunity to increase the thickness of the same to a point limited only by the porosity of the cake itself and the readiness with which it will take the wash water. By moving the filter into a vertical position and reversing the air current the cake is readily discharged.

Other uses for the silica diaphragm, which is an invention of J. E. Porter, of Syracuse, N. Y., are being sought in the arresting of flue dust in hot and acid fumes and in the making of catalytic plates for sulphuric acid manufacture.

Cyaniding Ores of Eastern Oregon.—In a brief note on some laboratory tests made on refractory ores of Eastern Oregon, Algernon Del Mar, writing in the *Eng. & Min. Jour.* for March 26, states it as his belief that an all-sliming system will prove successful on these ores. The precious metals are, as a rule, disseminated in a quartz or slate matrix. This was shown on a test of a representative ore in which the easily crushed portions assayed the same as the harder parts, while the small quantity of sulphide concentrates obtained did not assay twice as much as the original ore. The gold is not easily amalgamable. Cyanide processes have been tried, but not in their latest development. Experiments by the author showed that the finer the ore was ground, the better was the extraction. Financial reverses prevented the erection of slime filtration plants, so that only the laboratory tests are available as indicating the success of the all-sliming system.

Ammonia-Cyanide Extraction.—The alkaline nature of potassium cyanide and its selective action, permitting of the treatment of the most varied gangues, and allowing of the extraction of the values without much loss of the solvent, are assigned as the valuable features of potassium cyanide in the metallurgical industry by D. Mosher, writing in the *Pacific Miner* for March, 1910. Looking for a similarly valuable solvent for copper and zinc in ores carrying gold and silver, which would make it possible to handle these ores in a leaching process like cyanidation, the author believes that such a solvent is found in ammonia-cyanide. It is a stable, alkaline solvent, has selective action, extracting nothing from the gangue and only the ammonia soluble metals from the ore. Through the addition of cyanide to the ammonia, the extraction of gold and silver is also cheapened and simplified. The author expects that calcium cyanide will prove a source of cheap cyanogen, since he states that it can be made by heating cyanamide to a bright red heat in the presence of acetylene vapor or any gas rich in carbon. Cheap calcium cyanide with ammonia should make it possible to treat ore not now handled at a profit.

The chemistry of the ammonia metal combination shows that ammonia combines with metallic oxides and hydroxides to form soluble compounds. In this way silver, copper, zinc, nickel, cobalt, tungsten, uranium and vanadium form soluble ammonia compounds. The copper compound is given as $CuO \cdot (NH_3)_4 \cdot H_2O$; zinc as $ZnO \cdot (NH_3)_4 \cdot H_2O$; and nickel as $NiO \cdot (NH_3)_4 \cdot H_2O$. The solution is to be effected as much as possible in the cold, as the solvent power of the ammonia decreases with a rise in temperature and increases on cooling the solution down to the freezing point. In practice, it will take about ½ lb. to 1 lb. of NH_3 to dissolve 1 lb. of copper, zinc or nickel out of an ore. The recovery of the ammonia is an essential part of the process, and this is effected by the use of ammonia-tight apparatus. The recovery is said to be effected under less severe conditions than exist in ice making or in the Solvay process. In the boiling-out process the metallic oxides are precipitated as the ammonia distills off.

Copper.

Improvements at the Washoe Smelter.—Considerable interest always attaches to smelting and concentrating practice as carried out at the famous Washoe plant, in Montana, where operations are on a large scale and efficiency is kept at its highest, both financially and metallurgically. In the April issue of *Mines and Minerals* the latest changes and improvements at the plant are given. The concentrator is now treating 8000 to 9600 tons of ore per day. Heavier crushers are used and Huntington mills have been enlarged from 5 ft. to 6 ft. A larger-sized feed is sent to the coarse Hartz jigs and their screen area has been increased 58 per cent. In the McDougal roasters a new style of arm and rake have been introduced to facilitate repairs. In the new type the contact faces between arm and rake are protected against incrustation, so that broken rakes are easily removed. In the blast-furnace department considerable attention has been given to reducing air leaks in the air mains, bustle pipes and tuyeres. Another feature in this department is the reduction of the coke used, from 10.5 per cent to 9 per cent, by increasing the quantity of sulphides in the charge to give a sulphur content of 11 per cent to 12 per cent instead of 8 per cent to 9 per cent as formerly. In the converter department the principal change has been the use of second-class Butte ore for lining the converters. Formerly the Snowstorm (Idaho) ore was used for this purpose, being mixed with concentrator slime in the proportion of 2.9 tons ore to 1 ton slime. Second-class Butte ore is now similarly used and, although it contains more iron and sulphur than the Snowstorm, it is giving good service. Improvements have been made in the converter repair department which facilitate the relining operations. A Sanford portable welding machine has been introduced for autogenous welding and is used mostly in repairing the pressed-steel buckets of the slag conveyors.

Sintering Copper Ores.—An interesting discussion of the present status of copper smelting and of the need of a suitable process for sintering fine copper ores is given by Mr. Walter G. Perkins in the March, 1910, issue of the *Mining Magazine* (London). The author emphasizes the impossibility of divorcing the interests of the mine, concentrator and smelter, in view of the changing conditions which have led to the exploitation of very low-grade copper deposits. On account of the high silica and low iron and sulphur in copper concentrates from the low-grade "prophyry" deposits of the West, smelting by roasting and reverberatory practice is close to its limit, both technically and economically. The concentrator can make only a narrow saving lest the silica become excessive and the iron and sulphur prove insufficient for subsequent operations. If a greater saving is to be made more silica must go into the concentrate, and if this is true, improvements must be made in the smelting methods.

Reviewing the past improvements that have been made in reverberatory smelting in Montana and Utah, the author shows that there is still a limitation to the use of reverberatories and that they will not handle charges as refractory as those smelted in blast furnaces. He comes to the conclusion that "it is evident that improvements are demanded in smelting methods just as much as in water concentration if we are to save some of the 30 per cent to 40 per cent of the copper that goes over the

dump in the most modern of the large concentrating plants." And further: "The economic problem resolves itself into the cost of roasting in McDougal roasters with smelting in reverberatory furnaces, as against sintering followed by smelting in blast furnaces." Sintering machines have not yet solved the problem of successfully handling the fine concentrates now produced, but the author believed that "the only solution seems to be the development of sintering in place of roasting, and blast-furnace smelting in place of reverberatory."

Zinc and Lead.

Zinc-Lead Concentration.—The practice at the 400-ton concentrator of the United States Smelting Company, located at Midvale, Utah, is described in the April *Mines and Minerals* by Mr. LEROY PALMER. The ore treated carries about 9 per cent lead, 8 per cent to 9 per cent zinc, 13 per cent to 14 per cent iron and some copper, gold and silver. Two products are made; one, a lead concentrate carrying gold, silver and copper, which is smelted, and the other, a zinc-iron concentrate, which is subsequently submitted to an electrostatic separation. In the scheme of wet concentration adopted, all the ore receives at least a preliminary treatment on jigs of the Hartz type, from which lead concentrates and zinc middlings are produced. Nevell rolls, Colorado Iron Works cone classifiers and Sherman classifying tanks treat the product sent to Wilfley and Overstrom concentrating tables and Sherman slimers. The products of this system are lead concentrate, zinc concentrate, zinc-iron middling and tailing. The zinc-iron middling is further treated to prepare it for electrostatic separation. It is elevated to a dewatering wheel which sends the dewatered product to a bin and the water to a Callow tank. The bin product is reground in a Denver Engineering Works tube mill, which is an innovation that is found very satisfactory. Silex linings and flint pebbles are used, the linings lasting nine months and the pebbles wearing at the rate of ¼ lb. per ton of ore treated. Frenier pumps elevate the ground pulp to a settling tank. The overflow of the settler goes to a Callow tank, the spigot discharge of which is treated on a Sherman slimer, while the overflow goes to waste. The spigot discharge of the settler goes to a six-compartment Richard's pulsator classifier, the different products being treated on Overstrom and Wilfley tables. The mill is electrically driven and the power consumption is 0.4 hp per ton of ore treated. Concentration is on the basis of 1.83 tons of crude ore to 1 ton of concentrate. Extraction is 92 per cent to 95 per cent of the zinc and lead, 85 per cent to 90 per cent gold and silver, and 80 per cent copper.

Silver-Lead Smelting in Tasmania has never been a financial success, according to Mr. THEODORE KAPP, who describes the operation of the Tasmania Smelting Company in the April 2, 1910, issue of the *Eng. and Min. Journ.* The difficulties lie in the treatment of the low-grade ores at a profit. High-grade lead ores are more profitably shipped direct to European works, as the difference in freight between the ore and the silver-lead bullion is not great enough to counterbalance the costs of treatment in Tasmania. The introduction of the Huntington-Heberlein process of roasting greatly facilitated the treatment of low-grade ores, and while the smelter has not yet returned dividends to the investors, it has worked to the great advantage of the miners.

The Tasmania plant has automatic weighing and sampling departments, 12 Huntington-Heberlein roasters, three lead blast furnaces of the American type, 42 in. x 120 in. at the tuyeres, of which two are regularly in blast.

Mercury.

Mercury Reduction as practised at the Guadalupe mine in Santa Clara County, California, is described in the *Min. and Sci. Press* for March 26, 1910, by Mr. COURTENAY DEKALB. The mine has been operated intermittently since 1855. Cinnabar occurs in serpentine and is mined through a 2000-ft. adit reaching a depth of 700 ft. The furnaces are of the Litchfield type. Oil is used as fuel and 63 per cent of the total mercury recovered is obtained direct from the condensers, the remainder being extracted from the soot. Two blocks of furnaces are used, one for coarse ore, averaging 3 in. in size, and the other for the undersize. The furnaces are tall distillation chambers with inclined tiles so placed within that the ore fed at the top slides down in a zig-zag manner to the base, where it is drawn off hourly into cars. Outside the distillation chambers are the fire chambers. Heated gases pass from the latter into the former and upward through the ore, finally passing out near the top. The ore chambers at the Guadalupe furnaces are 40 ft. high and 3 ft. x 6 ft. in horizontal section. The upper part is constricted to a "throat" which is entirely filled by the ore being fed to the furnace. A dryer, independently fired, is above this constriction. The condensers are tandem brick chambers 12 ft. x 40 ft. in plan and 20 ft. high. From these the fume passes through flues expanding into smaller condensing chambers at intervals. Oil consumption is 1 bbl. per 10 tons of ore treated. The soot is treated on concrete tables, where it is hoed to facilitate the separation of the mercury. It is then mixed with ore and again fed to the furnaces. Labor consists of three men per shift of eight hours.

Electrochemistry.

Induction Furnace.—Concerning a new type of induction furnace, due to Mr. OTTO FRICK, the following information is given by Dr. F. Mollwo Perkin in the Lond. *Electrician* of March 18: Frick has designed a new induction furnace which, it is reported, has been tested and approved by the Krupp works in Essen. The furnace is said to have a capacity of 10 tons. The primary winding surrounds one arm of a rectangular transformer iron core; the same arm is also surrounded by the annular hearth. The other limbs of the core do not, as is usual in ordinary transformers, closely include the primary and secondary circuits of the transformer furnace. They are arranged at such a distance from them that the leakage fields, when the furnace is working, do not pass in any essential degree through the iron. By combining the primary winding facing a horizontal side of the hearth and a magnetic core, it is possible to use a primary coil having a flat, dish form. A coil of this design has a high magnetic reluctance in the leakage field which surrounds it, consequently the self-induction of the furnace is reduced.

Carbide and Cyanamide.—In a review of progress in electrochemistry in 1909, in the Lond. *Electrician* of March 18, F. MOLLWO PERKIN makes the following remarks: One has not heard so much in reference to the advances in the manufacture of cyanamide, but it is understood that in a good many works plant is being put down to convert the cyanamide into ammonium sulphate. This is produced by blowing steam over the cyanamide, and passing the ammonia so produced into sulphuric acid. The conversion of cyanamide into ammonia would rather point to its not having been found so satisfactory a fertilizer as was originally hoped. As to calcium carbide it is stated that in Australia the use of carbide is increasing rapidly and whereas the imports about five years ago were not more than 2500 tons they are estimated to have been 10,000 tons during 1909. The carbide is not only employed for illuminating purposes, but to work sprayers for killing blight and other purposes. In this case the carbide is placed in a strong iron vessel, water is allowed to act upon it and the pressure so produced (up to 100 lb. per square inch) is used to drive the insecticide through a nozzle.

End of Electrolytic Gold Precipitation in South Africa.—The Lancaster West Company, Transvaal, South Africa, has just completed new extractor-boxes for the zinc precipitation process, and the change from the Siemens-Halske system will be made immediately. According to the March, 1910, issue of *The Mining Magazine* (London), it is believed that this transition represents the final abandonment of electrolytic precipitation on the Rand. For some years before the war the process

had keen support, and many of the journals of the scientific societies indicate the great weight of opinion in its favor, owing to the saving in cyanide and the fineness of the bullion produced, even though it cannot be said to have ever gained a position of equal popularity with the zinc method. Under present conditions, with the improved efficiency of zinc precipitation and clean-up arrangements, the Siemens plant has had no chance of support, except in the case of the Lancaster, which until recently feared the capital expenditure involved in the alterations.

Rapid Electro-analysis with Stationary Electrodes was suggested about a year ago by Prof. J. T. Stoddard, of Smith College. The results obtained aroused considerable interest and some criticism, and caused a number of other investigators to look into the possibilities of Stoddard's method. In the March 31, 1910, issue of the *Jour. Soc. Chem. Ind.*, Dr. T. Slater Price and T. C. Humphreys present the results of their attempts to repeat Stoddard's work. Their procedure was as follows: In each case the amount of metal in a given volume of solution was determined electrolytically, using a rotating cathode, by a method which was known to give quantitative results. The analysis was then carried out according to Stoddard, using stationary electrodes and a current strong enough to heat the solution and increase the circulation effect produced by the gas bubbles coming off the anode. The electrolytes used were copper sulphate, nickel ammonium sulphate, silver nitrate, cadmium sulphate, zinc sulphate. The authors were unable to secure complete depositions in the period of time claimed by Stoddard, and came to the conclusion that for rapid electro-analysis stationary electrodes are not so reliable and satisfactory as rotating.

Those of our readers who are concerned with electro-analysis, especially in commercial practice, will be interested to compare these conclusions with those expressed in our correspondence columns in this issue by Allen P. Ford, metallurgist for the Crane Valve Company, Bridgeport, Conn., who gives practical conclusions favorable to the stationary electrodes of Stoddard.

Plating upon Aluminium.—The following process of E. C. Szarvasy for plating upon aluminium is mentioned by F. M. Perkin in the Lond. *Electrician* of March 18. The bath used is anhydrous methyl-alcohol with the copper or nickel salt dissolved in it. The surface of the aluminium is cleaned with a metal polish containing grease, the object of the grease being to protect the surface of the aluminium from atmospheric oxidation. The metal is then placed in the bath, the alcohol dissolves off the fat and the metal is then deposited in an adherent form on the aluminium.

Recent Metallurgical and Chemical Patents

Iron and Steel.

Alloy Steels.—Mr. Samuel S. Wales, of Munhall, Pa., patents an alloy steel which is claimed to have increased strength, great resistance to shocks and a high tensile strength. It contains carbon, manganese; nickel below 4 per cent; chromium, 0.5 per cent to 2 per cent; vanadium, 0.1 per cent to 0.5 per cent; titanium, 0.05 per cent to 1 per cent. (952,391, March 15, 1910.)

Another alloy steel patented by Mr. Wales and especially suitable for armor plates, with or without a carburized face, contains: carbon; manganese; nickel below 4 per cent; chromium below 2 per cent; vanadium 0.1 per cent to 0.5 per cent; copper less than 1 per cent. The addition of the copper within the limits named increases the tensile strength of the metal and increases the reduction in the area when tested to destruction. Both these patents are assigned to the Carnegie Steel Company. (952,392, March 15, 1910.)

Boron Steel for Transformer Sheets.—Dr. W. R. Whitney, of the General Electric Company, has found that the addition of the elements boron or beryllium increases the resisitvity of iron to a high degree, at the same time improving its mechanical properties and making a valuable steel for electric transformer sheets. The increased resistance causes, of course, a reduction of the eddy-current losses. The proportion of boron in the high-resistance alloy may vary from about 0.2 per cent to 5 per cent boron, but for most purposes the lower limit of boron content is preferable. The steel should be as free as possible from sulphur, phosphorus or other ingredients. The following suggestions of Dr. Whitney as to the rationale of the process are interesting. He believes that the resistivity of iron is increased by the presence of alloying elements to a degree inversely to their atomic wights, because of the increased number of molecules furnished by an element of low atomic weight per unit weight of alloy. In other words, a given weight of alloy, containing given percentages of iron and alloying element, will have a higher resistance if the atomic weight of the alloying element is low, as a given percentage of the element introduces a relatively greater number of molecules than the same percentage of an element of higher atomic weight. (952,290, March 15, 1910.)

Special Steel.—Mr. Charles R. Bryson, of Pittsburgh, Pa., patents a steel containing "chromium, 6 per cent; nickel, 3 per cent; tungsten, 0.5 per cent; silicon, 0.3 per cent; carbon, 0.6 per cent; iron, 89.177 per cent; phosphorus, 0.014 per cent; manganese, 0.4 per cent; sulphur, 0.009 per cent; vanadium, trace." The following properties are claimed for it: Excessive hardness, combined with toughness, and capability of resisting abrasion when brought into repeated contact with white or red-hot iron or steel. Also the peculiar property of non-cracking or fracturing when at a red heat and suddenly quenched in cold water, and furthermore, the property of non-deterioration when coming into repeated contact with white or red-hot iron or steel. For these reasons the steel is claimed to be "especially adaptable for the manufacture of butt or lap weld or seamless tubing, which art necessitates the use of balls, bell rings and stretcher bars, adjuncts commonly used in the production of the several methods of making metal tubes." (952,069, March 15, 1910.)

Cupola.—The construction of a cupola which is intended not only for melting, but for refining, is patented by Mr. Henry Johnson, of Saxilby, England. The cupola, which may be of the ordinary type with or without a receiver, is formed with a bath at the bottom capable of holding a suitable quantity of molten metal. A set of high-pressure blast twyers are provided in the side walls at the bottom of the bath, connected to a suitable air compressor or pressure blower, for the purpose of refining the metal. The bottom of the bath may be formed with a tapping hole through which the metal remaining at the end of a blow may be run off. A set of twyers are provided at a higher level than the blast twyers and are connected to a suitable fan or blower, these low-pressure twyers being approximately at the same level as the overflow, and being used to mix air or steam with the burning gases and support the combustion. (952,260, March 15, 1910.)

Combination Steel Process.—A new combination process, terminating in electric furnace treatment, has been devised by Mr. R. H. Wolff. The only claim of his patent refers to "the charging of a dephosphorized molten steel from a basic converter or open-hearth furnace on top of a basic slag, for the purpose of desulphurizing and deoxidizing the metal thoroughly and rapidly and then recharging this metal promptly in an electric furnace." The treatment in the electric furnace is made simply for the purpose of finishing and resting the metal, so that any gas or slag left in the metal may rise to the top. (946,302, Jan. 11, 1910.)

Gold and Silver.

Pulp Agitator.—In order to keep the particles in suspension in cyanide or other similar solution, R. W. GORDON, of Denver, Colo., has recently patented a novel device. The machine, as shown in Fig. 1, comprises a tank, in which a revolving conveyor raises the settled particles from the bottom of the tank discharging them at the top where they again settle to the bottom. The settling sands are caused to gather at a certain place on account of the construction of the lower wall of the tank and the insertion of a cone in the bottom of the tank. In operation the ore pulp is fed in any suitable manner. The rotation of the conveyor constantly elevates the settled particles of ore and discharges them at the top. They then settle both at the center of the tank, within the conveyor frame, and

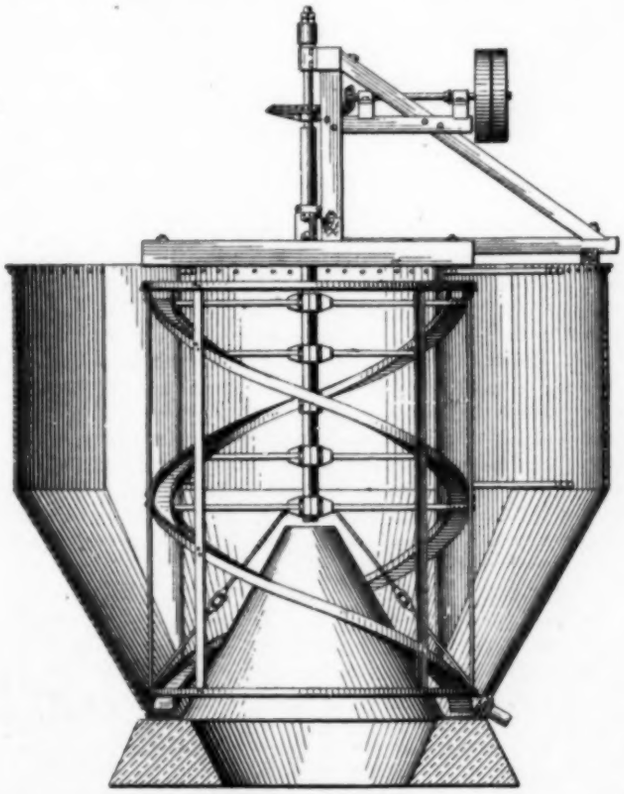


FIG. 1.—PULP AGITATOR.

in the outer part of the tank. This gives rise to three vertical currents, one upward in the path of the conveyor and two downward on each side. The rotation of the body of the pulp solution is prevented by baffles. The device is claimed to be particularly adapted for use ahead of filters, as it will deliver a homogeneous feed either continuously or intermittently. (954,511, 1910.)

Gold and Silver Extraction.—The mechanical treatment of slimes is the subject of a patent granted to A. F. CROSSE, of Johannesburg, Transvaal, South Africa. The principal features of the process were described in this journal for February, 1910, page 72. In brief, the process consists in treating the slimes with potassium cyanide solution in a cone-shaped agitator, obtaining a concentrated pulp underflow and a clear overflow liquid which is conducted directly to zinc boxes for precipitation, after which it is returned to be remixed with the pulp until practically the whole of the precious metal content is abstracted. The invention seeks to reduce the time required and to eliminate the necessity for filter presses. (951,940, March 15, 1910.)

Agitating Apparatus.—In order to thoroughly agitate sands or slimes containing gold and silver in order that they may be thoroughly leached by cyanide or other solvent, R. S. TOWNE, of New York, has patented an apparatus for agitating and aerating that class of material. The pulp is fed into the top of a leaching tank having a cone-shaped bottom and is circulated through a central shaft by means of a jet of air which carries the metal from the bottom of the tank upward through the circulation shaft from which it is discharged back into the tank. The circulation shaft has apertures at various heights which can be closed or opened as may seem desirable. Several different forms of tank are described in which the circulation shaft may be either within or without the main tank. (952,222, March 15, 1910.)

Zinc.

Improvement in Smelting Furnaces.—In order to avoid waste of ore at the time the smelting furnace is charged, C. A. WETTENGEL, of Caney, Kan., has patented a metal apron to be attached in front of the retorts in such a way that any of the fine ore which might otherwise go to waste when the retorts are charged is collected in such a manner that it is readily saved. A portion of the apron is removable so that the ash chute may be opened at the time the furnaces are discharged. (953,405, March 29, 1910.)

Tin.

Detinning Tin Scrap.—The application of a freezing process for detinning tin scrap has been made the basis of a patent recently granted to WALTER J. PHELPS, of Baltimore, Md. It has been found that when tin-coated scraps are subjected to extremely low temperature the tin has a tendency to separate from the steel or other metal coated by it. The apparatus which the inventor uses in accomplishing this end is an insulated drum in which rotates a perforated cylinder carrying the tin scrap. The axle or shaft of the cylinder is hollow and communicates with a number of nozzles placed along its length through which liquid air or some similar material is conducted. As the drum revolves and the liquid air acts on the tin the small particles fall through the perforations of the drum and are collected below. (952,351, March 15, 1910.)

Detinning.—Another novel detinning process, invented by Mr. CHARLES J. REED, of Philadelphia, consists of the following steps: The charge of tin scrap (tinned iron sheet scrap) is heated in a revolving drum in contact with particles of magnetite in a finely divided condition. When the charge is heated up to about the melting point of tin, the magnetic particles wipe off the fused or softened tin in pulverized form. Either simultaneously with this operation or subsequently in a second step the pulverized tin is removed from the scrap by means of a current air and is collected in a settling chamber or in textile bags. In the last step the residual mass is screened so as to separate the magnetite particles from the steel scrap. The distinction of this process from other detinning processes is that it is entirely mechanical. (950,115, Feb. 22, 1910.)

Electric Furnaces.

Radiation Resistor Furnace.—A batch of interesting patents has been granted, partly to Mr. JOHN THOMSON, of New York City, partly to Mr. F. A. J. FITZGERALD, of Niagara Falls, and partly to both jointly for a novel type of resistance furnace. All these patents are assigned to the Imbert Process Company, of New York. The common idea underlying all the designs is to heat the furnace charge by radiation from a resistor, which is generally placed above the charge.

The design of the resistor, which is made of carbon, varies in the different furnace designs, but in all cases great care is taken to counteract such deformations of the resistor (due to heating and cooling) which would change the uniformity of generation of heat in the resistor. For instance, if the resistor is an arch built up of wedge-shaped carbon blocks originally in uniform contact, then upon being heated, the arch would expand and would rise along its crown and the wedge-shaped carbon blocks would open at the upper surface of the arch and

the current would be confined to the under surface of the arch. To obviate this difficulty Thomson forms the wedge-shaped blocks so that when primarily set the lower portions of their faces are not in physical contact. Hence, when the arch is heated and expands and rises, the lower portion of the blocks will be forced into physical contact and the entire mass of the resistor will be in approximate balance electrically. (950,882, March 1, 1910.)

Another design of Mr. Thomson covers a resistor in form of a flat arch composed of wedge blocks. (950,881, March 1, 1910.)

In another design of Mr. Thomson, the resistor, in form of a horizontal plate, is built up of wedge-shaped sections, alternately reversed, so that on heating a direct right- and left-hand thrust due to expansion is produced and presses the upper sections upward, while on cooling and recontraction they fall down again. In general, the resistor plates are arranged in form of a loop or a series of loops folded back and forth and generally connected in direct circuit. This makes series-parallel connection of the different parts of the loop easy. (950,877, March 1.)

In another design of Mr. Thomson each section of the resistor consists of a plurality of grooved plates. When such plates are laid together, with the rounds of one plate in the hollows of another, the contacts will be in lines, and when a series of such plates are set between terminals, the several parts are interlocked and the resistor as a whole is self-sustaining, its weight and end-thrust being taken wholly by the terminals. Any side of such a resistor may readily be given greater compression than the opposite side, thereby correspondingly increasing the current density and temperature. (950,879, March 1.)

Another patent of Mr. Thomson refers to the application of the last named principle for the construction of a resistor rod in the center of a revolving furnace. (950,880, March 1.)

In another construction of Messrs. Thomson and FitzGerald the resistor is built up of round carbon rods, resting on a layer of refractory brick. The carbon rods are arranged in various layers. Since the mechanical pressure is strongest in the lowest layer, which rests on the refractory brick, there would be a danger of excessive heat along this layer. It is, therefore, advantageous to insulate the ends of the rods from each other where they rest on the refractories so that no current will flow through those parts of the rods, and hence no heat will be generated there. The chief advantage of the use of carbon rods is their low cost. (951,086, March 1.)

Another interesting resistor construction of Messrs. Thomson and FitzGerald is in form of a central cylindrical rod for a revolving furnace. The resistor consists of a cylindrical casing of recrystallized carborundum (a strong and very dense structure which may be heated to about 3600° Fahr. without damage, but is an excellent conductor of heat). Within this cylindrical carborundum casing granular or powdered carbon is provided, which represents the resistor proper. (950,878, March 1, 1910.)

To prevent the destruction of the highly-heated carbon resistor by the oxygen in the atmosphere Mr. FitzGerald proposes to introduce producer gas on account of its reducing nature into the chamber around the resistor. (950,905, March 1.)

This principle may be employed to construct a furnace which is partly heated by fuel and partly by electricity. The resistor consists of carbon rods resting upon a layer of refractory brick which forms the top of the melting chamber. The fuel gas is introduced into the upper chamber containing the resistors. The fuel gas is then mixed with air for combustion, the flame gases passing through the furnace in zigzag form to get a high thermal efficiency. Whenever the economical apex of the fuel heat is reached, the electric current is switched on to the primarily heated resistor and the higher range of temperatures is obtained from electrical energy. The fuel heating may also be made to reduce the loss of heat, produced from electrical energy. (950,904, March 1.)

An illustrated article from the FitzGerald and Bennie Laboratories, on this furnace and its use in zinc metallurgy, is reserved for our next issue.

Alumina Abrasives and Refractories.—The "artificial emery" process—first essentially a simple fusion of bauxite in the electric furnace—has undergone an interesting development in recent years in the hands of the Norton Company. Further evidence of this evolution is a batch of patents granted to Mr. Lewis E. Saunders, of Niagara Falls, N. Y., and to Mr. George N. Jeppson, of Worcester, Mass., all being assigned to the Norton Company. All the patents relate to special effects which the addition of certain impurities has on pure alumina.

A material consisting of alumina and titanium oxide (for instance, 94 per cent Al_2O_3 and 6 TiO_2, obtained by fusing in an electric furnace a mixture of alumina and rutile) is, according to Mr. Saunders, exceedingly hard, tough and massive, and of a granular or crystalline structure and has abrasive qualities of a high order. Its melting point is rather low compared with that of pure alumina. (954,767, April 12, 1910.)

A composition of alumina, silica and titanium oxide, free from iron, is, according to Mr. Saunders, useful as an abrasive and as a refractory material for the production of cast or molded articles. For instance, a product containing 92.5 per cent alumina, 3 silica and 4.5 titanium oxide, is very hard and tough, but is quite fusible as compared with pure alumina and is therefore more easily cast. It is brown in fracture and color and has a marked massive or adamantine character and excellent abrasive qualities. (954,768, April 12, 1910.)

A composition of alumina, titanium oxide and ferric oxide (containing, for instance, 1 or 2 per cent of titanium oxide and at least 2 to 4 per cent iron oxide, but no silica) is, according to Mr. Saunders, of blue or blue-black color; the crushed and graded abrasive has superior holding qualities for glue, etc., and is therefore particularly adapted for the preparation of abrasive paper or cloth; it is also particularly suited in the qualities of temper and hardness to the class of work to which abrasive paper or cloth is applied, as, for example, finishing leather and certain classes of metal work, more particularly disk grinding. The method of producing this material is both interesting and simple. In the old process, where the object is to reduce the impurities, bauxite is calcined to expel the water of hydration, and the material is then fused in an electric furnace between carbon electrodes, with the addition of carbon to the charge for the reduction of the oxides of iron, silicon and titanium. In the new process of Mr. Saunders commercial bauxite, containing both iron and titanium, is ground and calcined, and is then melted in an electric furnace with precaution to avoid strongly reducing conditions, that is to say, no carbon is added to the charge, and the charge is melted as rapidly as practicable between graphite electrodes. (954,766, April 12, 1910.)

Mr. Jeppson has found that the reduced impurities from the bauxite may be made to act as a bond for the refractory particles. Thus iron oxide and silica in bauxite will be reduced to ferro silicon and at a high temperature under oxidizing conditions this yields ferrous or ferric silicate or both, which are highly efficient bonding agents when properly disseminated through the mass. Mr. Jeppson prefers to incorporate with the product containing the reduced impurities a small proportion of another bonding agent, the function of which is to dissolve or flux and thereby disseminate the oxidation products of the reduced impurities, throughout the mass to be bonded. The procedure is as follows: Commercial bauxite is calcined in a rotary kiln and then melted in an electric furnace between carbon electrodes, with the addition of 5 per cent of carbon, so as to reduce the compounds of iron, silicon and titanium. The product is solidified, crushed and the nodules and detached particles of ferrosilicon are removed by hand-picking followed by magnetic separation. The material is then subjected to an oxidizing roast for the purpose of converting the remaining reduced impurities into oxidized products and is then separated into the required number of grades and sizes. The resulting

aluminous material is superficially coated with the oxidation products produced during the roasting operation, and is then mixed with water and 1 per cent of fire clay or high-melting point ceramic bond. The mass is molded or formed into refractory bricks or other desired shapes and fired in the usual way. The product is strong and extremely refractory to heat. (954,809, April 12, 1910.)

An abrasive for special uses such as the internal grinding of articles of steel, iron or the like is made, according to another process of Jeppson and Saunders, as follows: Alumina substantially free from oxides of iron, silicon, or titanium, is melted in an electric furnace between graphite electrodes, the charge being fed more rapidly than is the practice with impure alumina. It results from this relatively rapid feeding and from the use of graphite electrodes as distinguished from ordinary carbon, that the product undergoes but little reduction, possesses an essentially crystalline structure and is not contaminated with large amounts of aluminium carbide, the effect of the presence of which is to cause the mass to disintegrate on long exposure. The resulting pig or mass, usually nearly or quite white in color, and usually of a very marked crystalline structure, is broken up, crushed and subjected to an oxidizing roast to remove traces of carbide and to improve its bonding qualities. The particles are then graded and molded into the desired articles or implements by means of an appropriate bond, preferably ceramic bond. A suitable bond is a mixture of one part of ball clay with one part of feldspar, four ounces of this mixture being user for each pound of abrasive grains. Wheels so bonded possess the characteristic that under conditions of use the abrasive grains fracture in the bond, thus always presenting fresh and keen cutting points and edges to the work (since the grinding process is essentially a cutting process.) In this respect the wheel differs radically from those heretofore prepared from impure or partially purified bauxite or other commercial forms of alumina, the grains of which become dulled and glazed, and then break out from the bond without fracturing to any important extent. The bond is carefully prepared to admit of this effect, without which the efficiency of the wheel would be greatly diminished, since the work would be burned and the wheel would require frequent renewal of its cutting face by dressing. (954,808, April 12, 1910.)

Induction Furnace.—An induction furnace of the "disk-transformer" type is patented by Mr. C. W. SÖDERBERG, of Ski, near Christiania, Norway. The arrangement is shown in Fig. 2 in horizontal and vertical cross-section. The primary windings are distributed on four coils as a_1 a_2, inclosing both of the vertical parts b_1 and b_2 of the iron core. The secondary armature consists of a metal bath m_1 m_2, contained in a hearth m arranged between the primary coils and formed with an intermediate portion, and two semi-annular channels e_1 e_2, which together with the intermediate portion inclose both of the vertical pieces of the iron core. By the arrangement of four coils the leakage of the power lines is cut down. The lower primary coils are cooled by currents of air which pass through channels d_1 d_2 in the foundation of the furnace. (954,827, April 12, 1910.)

Induction Furnace with Electrodes.—A modified induction furnace for reduction processes is patented by Mr. K. A. F. HIORTH, of Christiania, Norway. The induction furnace is of the same construction as usual, with a ring-formed channel as secondary for the charge. The essential novel feature is the possibility of breaking the continuity of the ring channel, by inserting at some point a dividing wall. To get electric connection between the two sides of the wall, electrodes are placed at the two sides. They may be connected together either directly or through an auxiliary secondary coil wound around the magnetic iron core. The necessity of special electrodes is avoided if the dividing wall reaches only to the top of the molten metal bath proper, the electric connection being obtained by the slag, above the dividing wall. (954,804, April 12, 1910.)

Protection of Electrodes.—To protect those parts of a carbon electrode which are not embedded in the charge from burning or wasting away, Mr. H. C. HARRISON provides them with a protective coating or envelope. He dips the electrode in a bath containing some such material as common salt or fluorspar, which has itself a comparatively low melting point, and

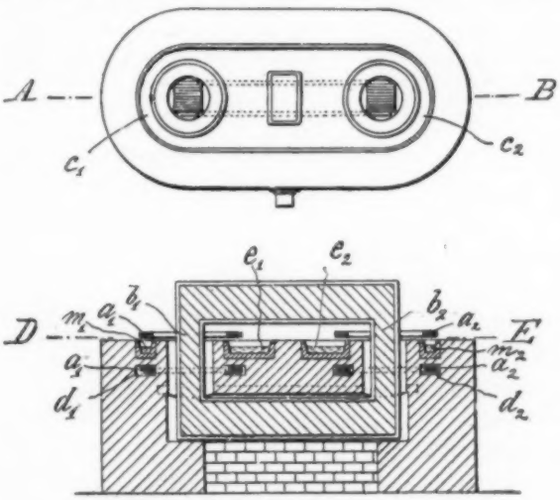


FIG. 2.—INDUCTION FURNACE.

which when in use forms a compound inert at the temperature to which it is to be subjected either as an oxidizing or as a reducing agent. If the electrode itself is made hot and dipped into a molten bath of common salt, for example, kept well fluid considerably above its melting point, after a short interval the electrode may be withdrawn and nearly all the superfluous salt will flow off leaving a glaze over the whole surface, which penetrates into the body of the electrode itself, the distance depending, among other things, on the porosity of the electrode, the length of the immersion and the fluidity of the bath. Another way is to dip the electrode into an aqueous solution of calcium chloride $CaCl_2$, which, after being heated in the air, forms, with the impurities present, a slag or coating consisting largely of CaO, and which will last as long as the electrode lasts. The patent is assigned to the Electro Metallurgical Company. (951,990, March 15, 1910.)

Vacuum Resistance Furnace.—In a vacuum furnace for exceedingly high temperatures, designed by Dr. A. O. APPELBERG, the principal feature is the use of a heating resistor of tungsten. This may be pressed into the desired form from finely powdered tungsten, but for convenience in manufacture it is desirable to add a small quantity of binding material to the tungsten powder and then squirt or mold the mixture into rods and blocks necessary for the construction of the furnace. A 50 per cent glucose solution is a suitable binder and may be added to the tungsten powder in the proportion of about five parts by weight. When glucose is used about 10 per cent of tungstic oxide is added to the mixture, so that when the mixture is heated up in the furnace there is enough oxygen present to eliminate all carbon and yield a refractory body of pure tungsten. This mixture when first molded or pressed is rather brittle and inclined to crumble, but by heating it in a vacuum to about 1300° C. it is rendered strong and relatively tough. After this treatment it can be machined and otherwise manipulated much like artificial graphite. Before the furnace is put into regular operation it is advisable to heat these tungsten parts to a temperature considerably higher than 1300° C. in order to drive out all vaporizable components, such as unreduced tungstic oxide, but this treatment can be conveniently carried out in the furnace itself after the latter has been assembled. A series of insulated superimposed rings of tungsten is used as a shield to prevent dissipations of heat toward the metal walls of the chamber and to reflect radiant heat on the crucible located

within the heating space. Since the entire vacuum chamber is free from carbon, very high temperatures may be produced without danger of contaminating the charge with carbon or carbides. The patent is assigned to the General Electric Company. (953,774, April 5, 1910.)

Amorphous Tungsten Powder.—The use of tungsten in the manufacture of electric lamp filaments has given rise to a great number of patents bearing on the production of tungsten in a suitable form. A recent process of JOHANNES SCHILLING, of Colonie Grunewald, near Berlin, Germany, depends on the tendency of tungsten compounds to break up into finely divided particles on being highly heated in the presence of ammonia. The resultant powder may be readily mixed with suitable binding agents and is designed to form a stronger filament. The inventor uses preferably meta—or para—tungstates of ammonium. The salt is heated in a closed tube to a temperature slightly above that of the disintegration of the salt. Hydrogen and ammonia gas are simultaneously led through the retort to produce a reducing atmosphere. The ammonia driven out of the salt is either wholly or partly dissociated and the nascent hydrogen acts as a very strong reducer and reduces the oxides of tungsten to the elementary substance. (950,869, March 1,

Electrolytic Processes.

Cleaning Articles.—Mr. HOWARD I. MANLEY patents the following method of cleaning metallic articles. He uses a receptacle of tin containing a solution of 97 per cent of sodium bicarbonate and 3 per cent of salt in the proportion of 1 oz. of this mixture to 1 gal. of water, heated to not less than 212° Fahr. The articles to be cleaned are introduced into the bath and are brought into direct contact with the tin surface. The cleaning of the article is effected "by a sort of electrolytic action which takes place on immersion thereof in the bath, the foreign matter which ordinarily tarnishes metal articles being precipitated to the tin surface." This explanation may hold for the cleaning of gold, solid and plated silver, nickel-plated and brass articles, for which the method is stated to be suitable. But it hardly explains the cleaning of cut-glass, glass, tile, etc., for which the method is also said to be applicable. (951,824, March 15, 1910.)

Mercury Cathode Cell for Sodium Chloride Electrolysis.—In our Vol. VI, p. 159, we noticed a patent of Mr. JASPER WHITING, of Boston, Mass., for a mercury cathode cell, in which there is no continuous circulation of the mercury or amalgam cathode, but the cathodic mercury is maintained in a quiescent state during the deposition of the sodium, but is transferred at regular intervals to an oxidizing compartment. Some modifications of this process and apparatus have now been patented by Mr. Whiting, but since the inventor is to present a paper on his process at the coming meeting of the American Electrochemical Society, we defer our report till then. (951,228 and 951,229, March 8.)

Electric Discharges Through Gases.

Producing Hydrocyanic Acid.—It is well known that hydrocyanic acid can be produced by passing a mixture of nitrogen and hydrogen over highly heated carbon. The apparatus for its production was described in our issue for February, 1910. (Vol. VIII, No. 2, page 10.) It can be appreciated, however, than an industrial application of the process would necessitate a cheap and simple method of producing the necessary gases, since the production of pure nitrogen and hydrogen would be too expensive. A solution of the problem is proposed in a process devised and patented by Dr. OTTO DIEFFENBACH and Mr. WILHELM MOLDENHAUER, in which they use Dowson gas, or producer gas, in their apparatus referred to above. This gas may have the following composition:

CO	27.6 vol. per cent.
H	15.3 vol. per cent.
CH_4	1.4 vol. per cent.
CO_2	3.9 vol. per cent.
N	51.8 vol. per cent.

When blown into the electric arc furnace with a velocity of 100-500 liters per kw-hour, a considerable concentrated HCN gas is produced. In passing a cooling device and absorption apparatus the HCN is removed and the waste gases are led to the gas container and may be used again. The expression "Dowson gas" is used to refer to a gas produced according to the formula

$$C + O = CO$$
$$C + H_2O = CO + H_2$$

starting from air and steam passed over the heated carbon. (954,080, April 5, 1910.)

Fixation of Atmospheric Nitrogen.—A new process devised by Mr. HENRY HOWARD, of Boston, Mass., for producing nitrogen oxides from air by arc discharges, is particularly interesting because it fulfils very well the two conditions which should be of fundamental importance if the purely thermal theory of oxidation of atmospheric nitrogen is correct: (1) the use of as high a temperature as possible for oxidizing the nitrogen, and (2) as quick a cooling as possible of the formed nitrogen oxides to prevent their dissociation. According to Mr. Howard's process the air is compressed, and is then subjected to the action of an electric arc which causes a great increase in pressure; it is then allowed to expand while doing sufficient work to absorb as much as practicable of its heat-energy, whereby rapid cooling is secured; this cycle is then repeated. In practice, the energy of the expanding gas will preferably be utilized for useful purposes, as for generating a portion of the electrical energy required for heating the gas, effecting a corresponding saving in the outside power required. The principle may be applied in various ways, as, for instance, in a machine operating on the principle of an internal-combustion engine, either of the four-cycle or two-cycle type. In the former case the first stroke of the piston serves to draw the gaseous mixture into the cylinder, and the second to compress it therein at about the moment of maximum compression or shortly before it is subjected to the heating effect of a powerful electric arc whereby its pressure is greatly increased. During the following or power stroke the heat-energy of the expanding gas is converted to a large extent into mechanical work with coincident chilling of the gas, further quantities of heat being dissipated by other means if desired. The final stroke of the cycle ejects the oxidized gas. In the two-cycle type the oxidized products are ejected and the fresh mixture admitted in the course of a single stroke. The principle may also be applied in a continuous manner by first compressing the gaseous mixture, and then passing it through a combustion chamber wherein it is strongly heated by a continuous or substantially continuous arc discharge, thereby increasing the volume of the mixture; the hot gases are then allowed to expand and do work as, for instance, by passing them through a turbine, the condition for the effective accomplishment of the reaction being that the expansion of the entire body of highly heated oxidized product shall follow the reaction as to minimize the dissociation thereof. (952,248, March 15, 1910.)

Ozone Generator.—In an ozonizer of Mr. FRANK M. ASHLEY, of New York, the electrodes between which the silent brush discharge takes place consist each of a number of bell-shaped metallic vessels, inserted one within the other, the oxygen or air to be ozonized being introduced through an axial opening in the central bell of one of the two electrodes. The rims of these two sets of bells are opposite each other, and the brush discharge passes from each rim to the opposite rim. (951,789, March 15, 1910.)

Welding.

Copper Solder.—As a solder or brazing material for connecting the confronting ends of two pieces of copper, for instance, of a trolley wire, a composition consisting of 38 gr. of copper and 35 gr. of borax is patented by Messrs. A. VASTAG and S. HORVATH, of McKees Rocks, Pa. (952,389, March 15, 1910.)

Aquadag as a Lubricant.

The readers of this journal are familiar with the merits of oildag as a lubricant, but up to this time little has been said about aquadag. Both oildag and aquadag are inventions of Dr. Edward G. Acheson and to him the world is indebted for these superior lubricants. Both contain deflocculated Acheson graphite, which remains in suspension. Oildag continues to win very pronounced favor, and it is evident that it is a general lubricant of great value.

Those who have tested aquadag as a lubricant for thread-cutting and machine-shop work in general have already come to appreciate its value. In Fig. 1 two pieces of pipe are shown. The particular machine on which these threads were cut was feeding with a very poor die. The factory had no other, neither could it procure one soon enough to fill a special order, so they were trying to do their best with a worn-out die, hoping at least to cut a sufficient number of end pieces to fill the order.

The piece of pipe at the left shows the kind of threads they were cutting with lard oil as a cooling lubricant. About 11 out of 12 pieces stripped as per illustration, and this despite the extra precaution that was taken to cut the thread by two passages of the die, instead of one. While in the midst of this work, they took all the lard oil out of the machine and put

FIG. 1.—COMPARISON OF THE USE OF LARD OIL (AT THE LEFT) AND AQUADAG (AT THE RIGHT) AS A LUBRICANT FOR THREAD CUTTING

in aquadag. They were astonished as well as gratified to find the die cut a wonderfully good thread with the aquadag as a cooling compound, and this, moreover, was done with one passage of the die, instead of two, as they were doing with the lard oil. The thread cut with aquadag as a lubricant is shown at the right. The threads cut with aquadag are cleaner than with lard oil, and much more definitely shaped. To use the foreman's words, "the threads cut are as good as those on a tap die."

The Niagara Machine Company, of Niagara Falls, N. Y., is another concern that has tested aquadag and determined its merits. Some weeks ago this company was cutting off in the lathe a large number of cold-rolled steel rods of average diameter about 1 in. Records showed that the average number of cuts the cutting-off tool would do, with one sharpening, was 60 when using an ordinary soap compound.

Having been asked to try deflocculated graphite in the form of aquadag, they mixed a small amount of it with their cutting compound and were greatly astonished, as well as gratified, to find that the tool did not blunt nearly so rapidly as before; in fact, the cutting-off tool actually made 980 cuts with only one sharpening. Fig. 2 is a reproduction of the 60 cuts made representing the maximum cutting done without aquadag, while Fig. 3 represents the actual 980 cuts made by the same tool in the same machine, the only difference being the addition of deflocculated graphite to the compound. It was observed that not only did the tool in the second case do about 16 times as much work as in the first instance, but also that the ends were very much smoother and the work was much better.

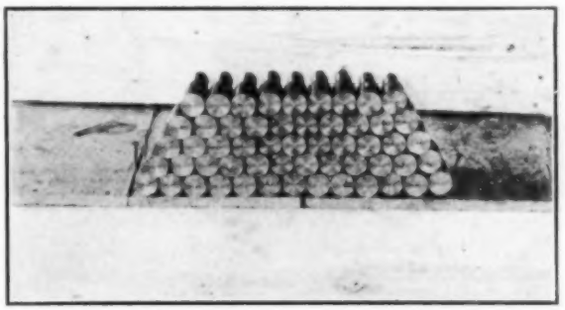


FIG. 2—RESULTS WITHOUT AQUADAG.

Still another point of merit associated with aquadag for machine-tool operation is that in boring and reaming a large number of holes in bronze bushings, it has been found that with ordinary cutting compound the hole is always about 0.0002 of an inch smaller than the reamer used, but through the addition of aquadag to this compound it has been found with a hole practically the full size of the reamer is cut.

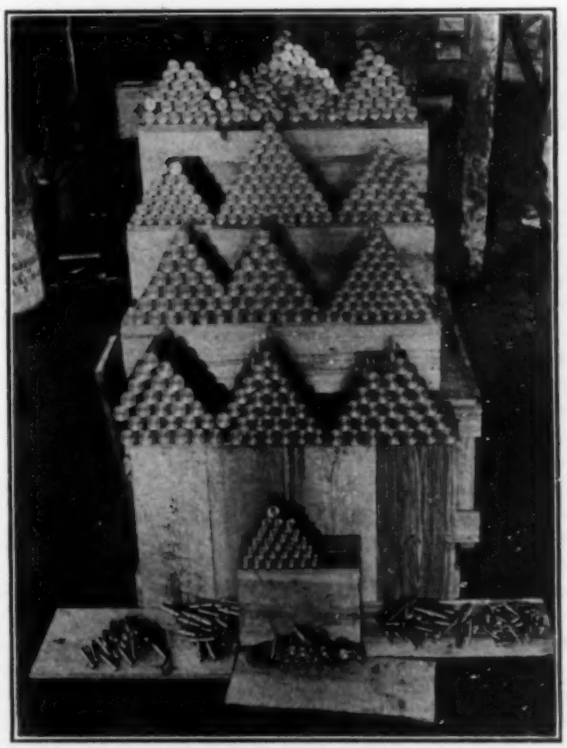


FIG. 3.—RESULTS WITH AQUADAG.

The general effect noticed in the use of aquadag in machine shop work is that it seems to afford considerable reduction in horse-power consumed, while there is considerable saving in the life of tools, and the work turned out is superior. Aquadag has been tried in practically every machine operation, namely:

lathe threading, lathe turning, die threading, boring, reaming, cutting off, planing, etc.

There are yet several points to be worked out in connection with the percentage of graphite to be used for the different purposes; whether it shall be mixed with compounds already on the market, or whether a separate aquadag solution shall be employed. All these questions are receiving careful consideration.

It might be added that aquadag has a wonderful field of usefulness before it as a lubricant for air compressors. Present practice is to use oil, the inflammable vapors of which cause serious explosions. The Refrigeration Committee of the National Fire Protection Association recently made this report:

"It is recommended that wherever in any system graphite can be used as a lubricant in compression cylinders, that it be done. This especially applies to air compressors used in dense air systems and for air compression for purposes other than refrigeration, as the temperature of the compression cylinders undoubtedly rises in some air systems to a point where inflammable vapors may be generated from lubrication oil."

Thus, a surprisingly wide field of usefulness opens before aquadag for the use suggested, and there can be no question but what it will afford high efficiency, undoubtedly saving many lives which might be lost through the use of more dangerous lubricants.

As the world comes to know the remarkable value of these lubricants containing deflocculated Acheson graphite, the greater must be the appreciation of the research work which resulted in their invention.

A New Hot Blast Stove.

There is not a regenerative stove on the market that does not involve special shaped brick in its construction, and some designs even go so far as to build entire linings of special brick, not one of which is listed in a brick manufacturer's catalog.

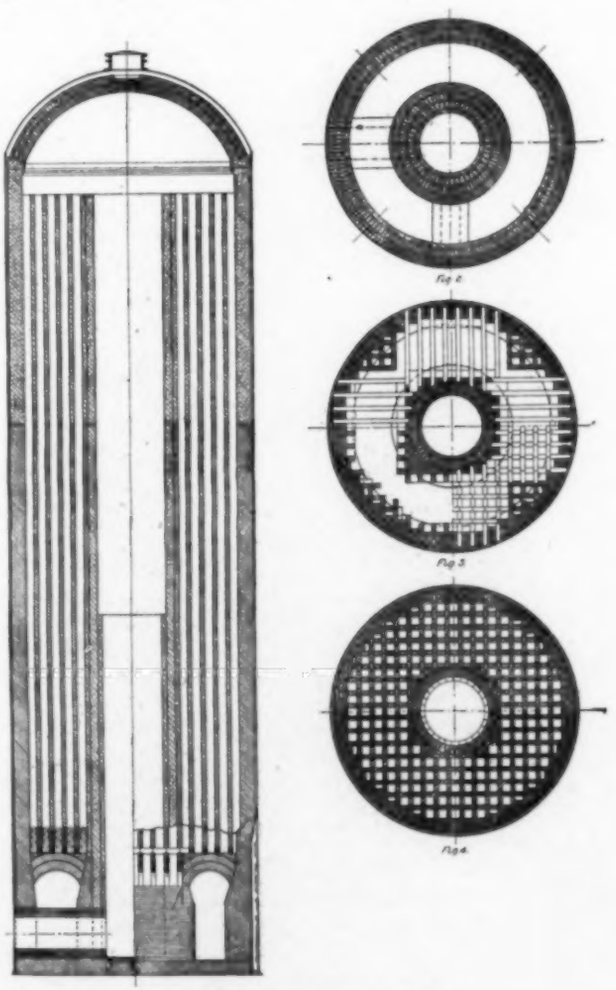
In order to build linings for stoves of this design it is frequently necessary for the brick manufacturer to make details of each particular brick and each brick must take its respective position in the lining or there is a misfit.

To manufacture special shapes other than are listed in brick manufacturers' catalogs, the manufacturer makes an extra charge on account of making new molds, extra labor and the time his drying floors and kilns are occupied for such special work. Delivery is also affected where special shapes are used, as they are very seldom found in the manufacturer's stock.

It is a well-known fact that in the manufacture of firebrick of standard size and shape, better results as to quality are obtained than is possible in the manufacture of brick of special shape larger in size than a 9-in. straight brick. The reason is that the manufacturer's equipment is best adapted to the making of standard shapes, and his employees are familiar with their manufacture, and that it is possible to make standard brick more accurately to dimension and to burn the smaller sizes of brick more uniformly throughout their entire section than is possible with a large or crooked special shape.

After a stove of this type has been in use for some time, and certain parts wear out by continuous use, it is always necessary to obtain duplicates of the special brick originally used, and this frequently necessitates considerable delay to obtain this material.

Mr. Alfred C. Nelson, having experienced considerable trouble in the building of stove linings where a large number of specials are used in their construction, has recently constructed a stove lining, using only such brick as are listed in the brick manufacturers' catalogs, with the exception of the dome plug, the tile supporting the checker, and the dome skew back. The arches shown in Fig. 1 were spanned in the earlier installation of this stove by using two 13½-in. x 6-in. x 2½-in. brick placed side by side. In place of these brick a specially designed 13½-in. x 6-in. x 4½-in. brick, with notches cut in each end, 9 in. apart to make a more substantial support for the checker work, as shown in Figs. 1 and 3, has been substituted. In order to make a more firm support for the dome the specially designed skew back above referred to is used. Outside of these two special shapes and the dome plug, the total of which figure about one-quarter of 1 per cent of the brick used in the construction of the stove lining, all brick that go to make up the lining can be bought from the brick manufacturer's stock, and of these about 85 per cent are standard 9-in. straight brick, 9 in. x 4½ in. x 2½ in., and 14¾ per cent consist of standard 9-in. keys, wedges, arch and circle brick such as a brick manufacturer usually carries in stock in large quantities and can ship immediately.



FIGS. 1, 2, 3, 4.—HOT-BLAST STOVE.

Patents were issued on a stove of this design June 22, 1909. Fig. 1 shows a vertical section of the lining. Fig. 2 shows horizontal section taken at the bottom of the lining just above the various openings. A wall 22½ in. thick is used for supporting the stove, this wall being made of keys, straights and circle brick. Fig. 3 shows a horizontal section taken in quarters just below the arches, top of arches and top of special brick spanning the arches. The arches (Fig. 1) are 18 in. deep and are made of two courses of wedge brick. Fig. 4 shows horizontal section taken of two courses of brick in the checkers, one just above the other, and indicates how every joint is broken, and each brick is absolutely bonded with adjacent brick without a break, making it practically impossible for any part to become disarranged, making a strong, solid structure.

The amount of heating surface compares favorably with other stoves now in use, and in some sizes gives a greater area. In

plants where the gas is thoroughly washed it is found desirable to use a smaller checker. This stove can be laid up to excellent advantage with a 6¼-in. square checker, using standard brick the same as in the case of the 9-in. checker, and the amount of heating surface will be somewhat greater than with the 9-in.

This type of lining has already been adapted to stove shells having a diameter of 18 ft., 19 ft., 20 ft. and 22 ft. There are stoves now in satisfactory operation at four different plants using this style of lining, and a number of stoves are now in process of construction.

This lining is adaptable to any two-pass stove regardless of its openings, and whether it has formerly been lined with side or central combustion chamber.

Mr. Arthur G. McKee, engineer, Rockefeller Building, Cleveland, Ohio, with whom Mr. Nelson has been associated for some time, is now introducing this stove to the furnacemen of the country.

Electrostatic Ore Separation.

When particles of minerals are brought into contact with one pole of a sufficiently high-voltage source of electricity they assume the electric charge with varying degrees of rapidity, depending on their electric conductivity. This varying degree of conductivity, together with the fundamental principle that bodies carrying electric charges of unlike polarities attract one another, while bodies carrying charges of like polarities repel one another, forms the basis of electrostatic ore separation.

If a mixture of mineral particles be subjected to the influence of an electric charge, there will be a difference in the readiness with which that charge is acquired by the various minerals, and there will also be a difference in the time in which the minerals will become discharged when brought in contact with a conducting surface.

Minerals may be broadly classified into good and poor conductors. If a mixture of good and poor conductors be brought into contact with a surface highly electrically charged, the good conductors immediately become charged to the same condition and are repelled from it, while the poor conductors require a longer time to acquire the charge and if the electrical conditions are right may cling to the surface for a considerable period. Or if such a mixture be in some manner first charged with one kind of electricity and then suddenly brought into contact with a surface charged with the opposite polarity, the good conductors will instantly lose their first charge and be repelled from the surface while the poor conductors, carrying an opposite charge, will not lose it so quickly and will therefore be attracted by the surface until their first charge is neutralized or until they are brushed off. Again, instead of moving the mixed minerals progressively into regions of different electrical conditions, the surface upon which they rest may be suddenly changed in its electrical polarity, whereupon the good conductors will follow the change more rapidly than the poor conductors.

To utilize these principles is the object of the Huff electrostatic ore separator built by the Huff Electrostatic Separator Company, 60 India Street, Boston, Mass. The illustration, Fig. 1, shows the application of the principle, and Fig. 2 shows the finished machine as it is now used in several plants. In Fig. 1 the path of the better conductors is represented by (1) and that of the poorer conductors by (2) with certain types of electrification, while with other types of electrification the path of the better conductors is (2) and the path of the poorer conductors is (3).

The separator is built in cast-iron sections, two electrodes to each section. This arrangement permits of flexibility in construction and convenience in shipping and handling. A four-section machine is 8 ft. high, 6 ft. 6 in. long and 18 in. wide. All parts charged to high potential are insulated from the grounded machine and carefully shielded from accidental contact. The electrical fields are concentrated and confined almost entirely to the spaces in which the separations take place.

One improvement in the Huff process is the use of special generators similar to the dynamos of an electric lighting plant to produce the desired electrical wave, thus displacing the static machine with all of its attendant difficulties which formerly made electrostatic separation so troublesome. This electrical apparatus is entirely independent of atmospheric conditions and provides uniform and steady operation of the plant. The strength of the separating field is constant, and

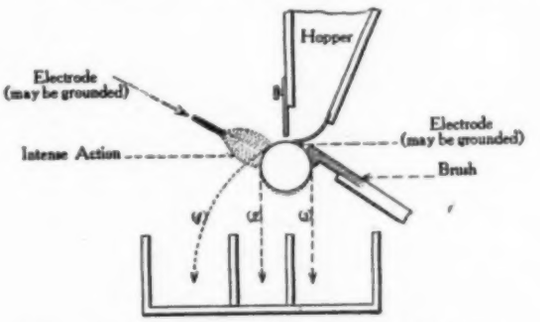


FIG. 1.—PRINCIPLE OF ELECTROSTATIC SEPARATION.

can be increased or decreased at will.

Ores for electrostatic separation must be dry and preferably free from dust. Fine crushing is not always necessary, nor is fine sizing, though coarse sizing is usually advisable. Power and labor costs are small items in the operation of the Huff machines. A ¼-hp machine is sufficient to turn the electrodes of the machine illustrated and to supply the electrical power.

As stated before, minerals may be divided into two classes—good and poor conductors. Minerals of the one class may be separated from those of the other and in many cases minerals in the same class may be separated from each other. If two

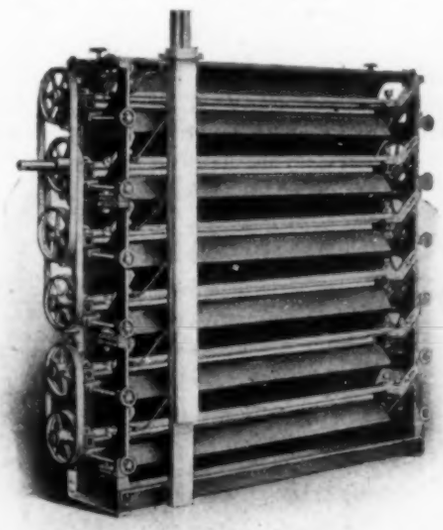


FIG. 2.—ELECTROSTATIC SEPARATOR.

minerals cannot be separated from each other in their natural condition, the conductivity of one may be altered by artificial means, such as by heat, or by chemical or electrochemical action. Thus, a poorly conductive carbonate may be converted by roasting into a conductive oxide. The following is a general classification of the common minerals according to their conductivity:

Good Conductors.

Most sulphides; such as pyrite, galena, chalcopyrite and chalcocite.

Native metals, such as gold and copper.

Some oxides, such as magnetite and hematite.

Certain arsenic and antimony compounds of copper and silver, such as pyrargyrite and tetrahedrite.

Biotite.

Graphite.

Poor Conductors.

Most silicious minerals and rocks, such as quartzite and sandstone; granite, porphyry and andesite; epidote, garnet and calamine.

Most carbonates, such as calcite and siderite.

Most sulphates, such as barite and gypsum.

Zinc sulphide, as sphalerite or blende.

Electrostatic concentration has some unique and exclusive fields of operation, such as general concentration of ores in dry and arid regions; the separation of copper and lead-silver ores from heavy gangues like garnet, barite and epidote; the concentration of carbonates of copper in limestone; the separation without previous roasting of zinc minerals from complex ores; and the concentration of molybdenite, graphite and monazite.

One of the most important metallurgical problems to which the Huff electrostatic separator is being applied is the treatment of complex sulphide ore containing zinc. A great many Western ores contain zinc, which has always been a source of trouble and loss to both miner and smelter of copper and lead-bearing ores. The latter finds the zinc detrimental to profitable smelting and the former has to stand the penalty which the smelter is obliged to impose. Finally, the zinc itself is not saved, thus increasing the total loss in mining and smelting.

It has been the successful application of electrostatic separation which has solved the problem of the miner with zinc in his ores. By this process the lead, copper, gold and silver bearing minerals may be separated from the zinc, thus producing two materials each suited for its special treatment, and much sought after by different smelters. The lead or copper smelter is no longer handicapped by a small percentage of zinc, and the zinc smelter is provided with a new supply of clean high-grade zinc concentrates.

Generators for Electrometallurgical Work.

BY M. BERTHOLD.

The steadily increasing demand for low-voltage generators for electrometallurgical work has been the stimulus in the further development of such apparatus by the Ideal Electric & Manufacturing Company, of Mansfield, Ohio. Some details on the principal features of their designs are given in the following notes.

FIG. 1.—LOW-VOLTAGE DYNAMO FOR ELECTROLYTIC WORK.

The principal considerations in the production of low-voltage generators, in particular those of very large ampere capacity, center upon the following points:

Heating.—The temperature elevation above the surrounding atmosphere is limited to 35° C. in any part of the machine when the generator is operated at proper speed continuously under full load. All parts of the machine, such as the armature core, winding and commutator, are well ventilated; besides all conductors are worked at low-current density. Thus, the insulation is best preserved which furnishes a guarantee against any service interruption.

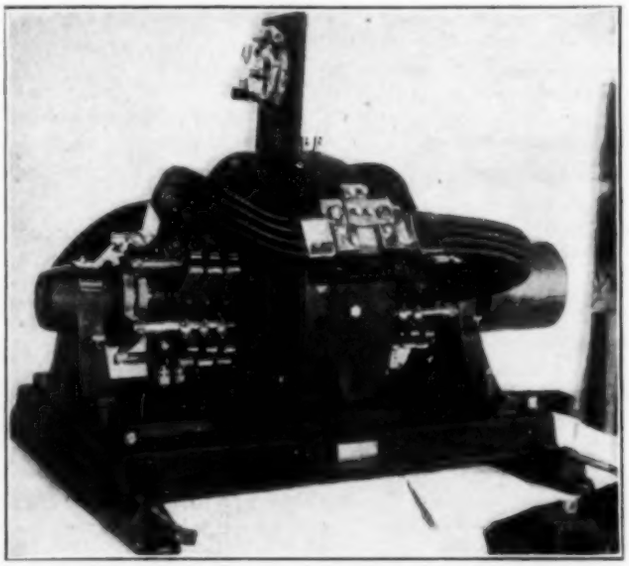


FIG. 2.—LOW-VOLTAGE DYNAMO FOR ELECTROLYTIC WORK.

Special care has been taken to eliminate completely the local heating of current-carrying contacts for frequent temperature changes due to the operation on light and heavy loads and subsequent shutdown tend to loosen the contacts. The surfaces are carefully finished, liberally proportioned and made easily accessible for inspection.

Armature Winding, Commutator and Brushes.—One or two commutators, according to the rating, are provided, and a construction of the most durable form for this sensitive part of the machine is selected. Sparkless commutation of the large currents is essential and the satisfactory working depends upon the electrical design as well as upon the construction of the commutator and brushes. The commutator is designed with a large number of segments in order to reduce the local currents which flow in the armature coils undergoing commutation. Because of the extremely low resistance of the armature winding, a slight irregularity in the shape of one or another coil leads to an unbalancing of the armature circuit or circuits. By the method employed in machine forming all the coils to like form and length, the armature circuits are made perfectly symmetrical and are thus equalized with mechanical precision.

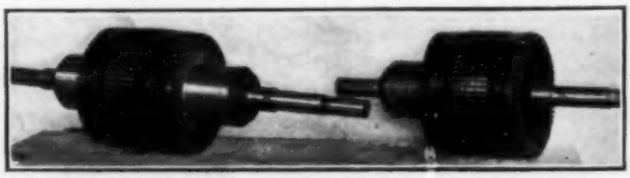


FIG. 3.—ARMATURE AND COMMUTATOR CONSTRUCTION.

The current is conducted to the terminal boards by means of the brushes contacting with the holders through large surfaces. Copper leaves carry the current to suitable clamping devices on the stems, independent of the spring mechanism

necessary for the adjustment of the brush tension. Thus extremely cool operation is maintained even at comparatively heavy loads maintained during long periods.

Brush Support.—The brush-holders, brushes, stems and cables, representing considerable weight, are supported on the frame in preference to supporting same at the extreme end of the bearing housing. This construction provides also for a greater freedom in the accessibility desirable for the adjustment of the brushes during operation, and eliminates any vibration necessarily so injurious to the proper working.

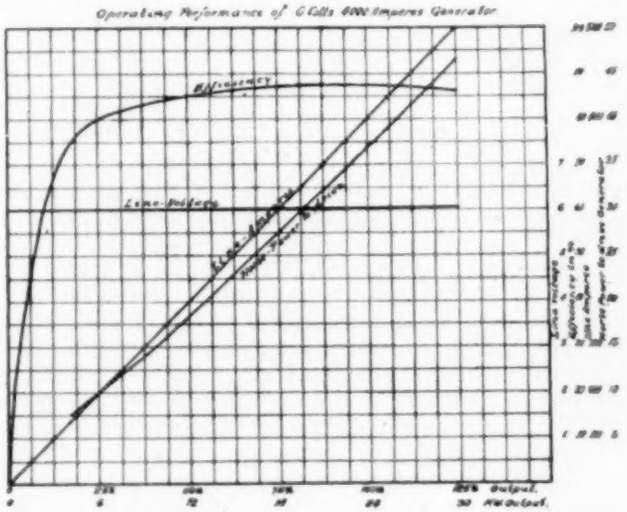


FIG. 4.—TEST CURVES OF GENERATOR.

Voltage Regulation and Excitation.—The standard machines are furnished as compound-wound generators and the compounding is so adjusted as to practically maintain constant the voltage within the guaranteed rating, when the generator is operated at practically constant speed. All machines up to the largest ampere capacities and above 5 volts at the terminals are self-excited.

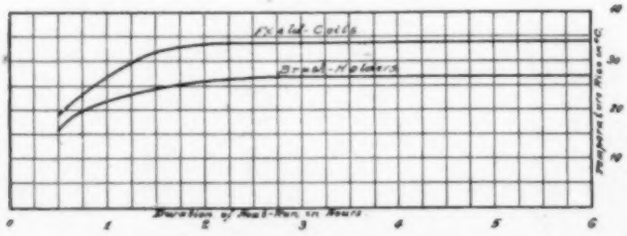


FIG. 5.—TEMPERATURE TEST.

Fig 1 and Fig. 2 illustrate machines of the standard type above 2000-amp line current. Fig. 3 gives a detail view of armatures showing the commutator construction and the armature winding.

The curve sheets Fig. 4 show the operating performance of a 4000-amp and 6-volt, compound-wound generator, while Fig. 5 gives a record of the maximum temperature rise of this generator attained during continuous full-load operation.

The performance given in the above curve sheets apply in general to all the standard ratings and each generator, after completion, is subjected to a full-load test.

Smelters in Colorado.—The Traylor Engineering Company, Allentown, Pa., is erecting two smelting plants in Colorado for private smelting companies. One is at Alma, near Leadville, and is being built for a company owning and leasing mines there. The other is at Red Mountain, near Ouray, in the San Juan country.

System for Utilizing the Heat of Blast-Furnace Slag.

When it is considered that one ton of molten slag from a blast furnace contains (on the average) sufficient available heat to produce upward of half a ton of steam (say, 30,000 cu. ft.), any system that can utilize that amount of energy in the form of steam power must be of such economic importance as to merit the consideration of the management of smelting works generally.

Prior to the advent of the low-pressure (1-lb. gage) steam turbine various attempts have been made to utilize the heat energy contained in molten slags in the form of high-pressure steam, but the practical difficulties experienced in admitting the molten material and removing the cooled or granulated product from a closed high-pressure steam generator have been the chief reasons why such an important and economical source of power has not been utilized.

In order to render practical any system for utilizing the heat contained in molten slag from iron, copper and lead furnaces it is, in the opinion of Mr. Claude Vautin of London, the inventor of the present system, necessary that the following conditions be fulfilled:

(a) The use of the steam at or about atmospheric pressure.

(b) The continuous admission to, and removal of the slag from the steam generator.

(c) The prevention of any escape of steam from, or of the admission of air into, the generator at the point of slag admission and removal.

The first of the above conditions is made possible by the utilization of the modern low-pressure steam turbine, the great possibilities of which are daily receiving the closer attention of all engineers.

The second is fulfilled by means of a specially designed and constructed trapped-slag inlet for the admission of the molten slag, and of a suitable trapped elevator for the removal of the granulated slag from the steam generator.

The third is made possible by means of a trapped-slag inlet so constructed as to freely permit the molten slag to enter the generator without the escape of the low-pressure steam therefrom, and at the same time to preclude the possibility of air entering same, thus ensuring the efficient working of the condenser connected with the low-pressure steam turbine.

Description of System and Plant.

The system consists in continuously bringing molten slag into water contained in a closed vessel, the slag being chilled or granulated and continuously removed from the vessel. The low-pressure steam produced is led either to a low-pressure steam turbine or into a heat accumulator (e.g., of the Rateau type) connected with the turbine and condenser.

The plant, therefore, consists of a steam generator, a low-pressure steam turbine connected with an electric generator, and a condenser; the addition of a heat accumulator is recommended in cases where variation in the supply of molten slag to the steam generator is likely.

The steam generator consists of a closed vessel containing water, to which is suitably attached a trapped inlet for the admission of the molten slag, an elevator for removing the granulated slag, and a centrifugal pump. The latter is for the purpose of applying boiling water from the generator to the granulation of the slag, and will be referred to later.

The steam turbine, electric generator and condenser, being well-known machines, need no detailed description.

The form of the generator can be varied to specific requirements. Generally one of the following types is recommended:

(a) An iron or steel vessel consisting of one vertical and three sloping walls coming to a point which forms the boot of the slag elevator.

(b) A boiler shell of the necessary diameter and length, containing a trough into which the molten slag falls from the

trapped inlet, where it is struck by a stream of hot water from a centrifugal pump and effectively granulated. This form of generator is provided with a slag elevator at the farther end.

The inlet to the generator varies with the class of slag to be treated; if the slag flows freely it will consist of an inner lip over which the flow into the steam generator takes place and a partition arranged so that the slag passes underneath it; the level of the slag is adjusted to a height such that a steam pressure in the generator of about 1 lb. per square inch is balanced by a head of about 8 in. of molten slag. This form of trap, besides preventing any escape of steam, precludes the admission of any air into the generator, a precaution which, as previously stated, is necessary for the best working of the condenser connected with the steam turbine.

Should the slags under treatment be viscid or "quick setting," a modified design is employed which obviates the necessity of a slag trap, while effectively preventing the escape of steam from, or the admission of air to, the generator.

The elevator for the removal of the granulated slag from steam generator is arranged so that any air carried down by the buckets is prevented from entering into the generator and from thus decreasing the efficiency of the condenser.

The slag-trap inlet is easily removable from the generator for repair; each generator is provided with two trap inlets, so that while one may be under repair the second is in operation; any stoppage in action is thus prevented.

Means are provided to prevent the escape of steam from the generator during the removal or repair of an inlet. The shape and construction of the slag inlets is such that the inner lip over which the slag flows into the generator can be readily barred and kept open.

It is the low pressure which the Vautin system employs that allows the heat contained in molten slags to be utilized for power production. This will be readily appreciated when it is pointed out that a steam pressure of, say, 1 lb. (gage pressure) is balanced by a head of about 2 ft. of water in the slag elevator casing and by about 8 in. of molten slag in the slag-trap inlet.

The granulation of the molten slag is effected by causing it to be brought into contact with a stream of hot water drawn from the generator and delivered at a high velocity by a centrifugal pump. This method of granulation prevents any condensation of the steam generated, as both are practically at the same temperature.

In order to provide an even and continuous flow of slag into the generator, where two or more blast furnaces are in operation, it is advisable to add a slag storage system, in the form of a reverberatory furnace, into which the slag from the blast furnace is tapped from time to time, or dumped from slag cars. From this storage the molten material is run continuously into the generator. The fuel here necessary to maintain the slags at the temperature at which they flow from the blast furnace is comparatively small, but little more than the radiation losses requiring to be made good. In lead and copper smelting works the reverberatory storage hearth also acts as a settler and permits of the recovery of a considerable amount of matte (or metal).

The granulated slag from the generator may be fed from the elevator to a belt conveyor and removed to the dumps, a system usually more economical than the usual slag-car method. The cost of operating the Vautin system is determined solely by the running and up-keep of the slag elevator, centrifugal pump and slag-trap inlet, plus the ordinary interest and depreciation allowances. Any good type of low-pressure turbine can be used in connection with this system of steam generation.

Tests have proved that no ill effects upon the blades of steam turbines of the Rateau type are produced by the small amounts of sulphuretted hydrogen which sometimes arise from the granulation of certain slags in water.

Thermal Data.

The following thermal data are submitted by the inventor. The available heat contained in the average copper and lead blast-furnace slag is from 318 to 350 calories per kilo. From this must be deducted the heat retained by the slag removed from the steam generator at a temperature of 100° C., with a specific heat of 0.18, or a total of 18 calories. Figuring from a basis of 1000 kilos of slag per hour at its lowest available heat of 318 calories per kilo we have $1000 \times 318 = 318{,}000$ calories available heat, from which must be deducted $1000 \times 100 \times 0.18 = 18{,}000$ calories retained in the slag, leaving 300,000 calories for conversion of water into steam of atmospheric pressure at sea level. As each kilo of water at 15° C. will require $85 + 537 = 622$ calories, it should be possible to produce $300{,}000 \div 622 = 482$ kilos of steam for 1000 kilos of slag per hour. Assuming a consumption of steam in a good, modern low-pressure turbine to be 15 kilos per hp-hour, we have $482 \div 15 = 32$ hp.

From this figure deduct, say, 8 hp to cover all possible contingencies, such as variation of temperature of slag, radiation losses in steam generator, etc., and we have left 24 hp per ton of slag per hour, or 1 hp per ton of slag per day of 24 hours.

Saving in Coal Bill.

The following figures by the inventor show the estimated saving in the coal bill of a copper or lead smelter generating 1000 hp by means of coal as compared with the cost of generating the same power from 1000 tons of slag per day. Assuming the consumption of 1.5 kilos (3 lb.) of coal per hp-hour and a cost of 20 shillings ($5) per metric ton (or 2000 lb), Mr. Vautin calculates the cost of 1000 hp for a year:

Steam from coal ($8760 \times 3 \times 1000 \times \$5$)	$65,700
Steam from slag (estimated by the inventor)	7,500
Estimated saving in cost of fuel per year	$58,200

The Use of Recording Velocity Gages in Boiler Plants.

By F. Hymans, M.E.

The introduction of economy in the boiler-room has created a demand for an instrument that will give an accurate record of the process of combustion and of the performance of the mechanical stoker or fireman. The apparatus described in this article is intended to solve this problem. The present-day draft gage has proved entirely inadequate. Under certain weather conditions, for instance, the wind may exercise a suction and the draft gage would indicate a vacuum even though the damper is entirely closed. The varying thickness of the bed of fuel, the varying constitution of the fuel, the formation of clinkers offer a varying resistance to the passage of air through the grate, and though the draft gage may indicate one and the same vacuum, the amount of gas that passes through the flues may be wholly different.

The recording velocity gage of the "Hydro" Manufacturing Company, 721 Lewis Block, Pittsburgh, Pa., overcomes the difficulty by measuring the difference of pressure of the combustion gas at a point above the grate surface and at a point close to the damper. This differential pressure is the pressure that forces the gases of combustion through the flues; it is solely dependent upon the velocity of the gases and it is, therefore at once a measure for (1) the velocity of the combustion gases, (2) the amount of the combustion gases. And since the latter stands in intimate relation to the amount of fuel and air, the indications of the instrument are further a measure for (3) the amount of fuel burned on the grate, and (4) the amount of air used in the process of combustion.

This illustrates at once the fuel-saving possibilities of the instrument and still more so when it is remembered that the velocity of the combustion gases is a direct measure for the

time required to pass through the flues, i.e., for the time the gases have been in contact with the heating surfaces. Therefore excessive differential pressures are indicative of high stack temperatures and of loss.

In how far the instrument may be used as a check on the

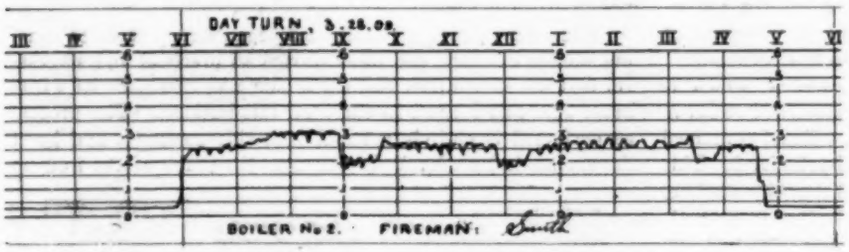


FIG. 1.—RECORD CHART OF HAND-FIRED BOILER.

fireman, Fig. 1 clearly shows. Working hours at the factory where the diagram is taken are from 6:30 a. m. to 5 p. m. The charts shows that the fireman began getting up steam half an hour earlier, at 6 a. m., the damper being closed during the night and the differential pressure being 0.225 in. At 6 a. m. he opened the damper, the differential pressure increasing at once. After that the differential pressure gradually increased and the chart shows in nearly regular intervals downward pointed curves. Such a point occurs when the fire door is opened, i.e., when fresh fuel is added to the grate.

The curve would point upward if the damper is not closed simultaneously with the opening of the fire door, as the opening of the fire door permits the air to enter direct, eliminating the resistance of the grate against the passage of the air, and thereby permitting a greater amount of air to enter the flues. This the instrument indicates by an increase of the differential pressure and the curve points upward.

On the chart, Fig. 1, the curves properly point downward, showing that the fireman decreased the amount of air entering the furnace by partly closing his damper. The pointed curves are, therefore, a fine check on the regularity of the combustion process. Between 9 a. m. and 10 a. m., the differential pressure drops for a long time, indicating the cleaning of the fire from clinkers with a simultaneous greatly closed damper. Thereafter the combustion process continues regularly as indicated by the downward pointed curves and at about 12 m. the drop of the differential pressure indicates a second deposit of clinkers.

Between 1:30 p. m. and 3 p. m., the points of the curves are less sharp, indicating the fire door remained open longer than previously. This was made necessary as the fireman at that time had to use wood and waste of the factory for fuel. Between 3 p. m. and 4 p. m., the chart indicates another deposit of clinkers. At 4:30, half an hour before close of business, the differential pressure drops again to 0.025 in., indicating that the fireman has banked his fire for the night.

While the foregoing is an excellent example of the check the instrument permits of the work of the fireman, it is equally useful for mechanical stokers for the simple reason that whatever the type or make of the furnace, the speed and amount of the combustion gases should be a minimum for the best

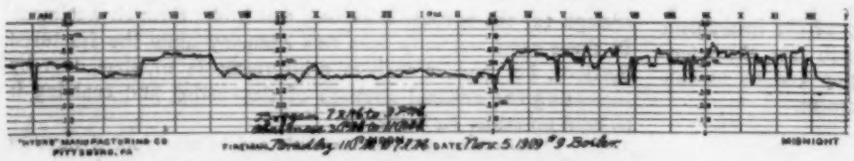


FIG. 2.—RECORD CHART WITH MECHANICAL STOKER.

results. With this point in view a still more important use can be made of the instrument which of necessity must result in prevention of waste. A few observations will in any boiler plant determine the minimum differential pressure that is required to maintain the steam pressure under the varying loads. These once determined the fireman or mechanical stoker should be made to regulate the combustion process in accordance. The result will be the maintenance of the most economical velocity and amount of combustion gases resulting in the most economical consumption of fuel.

The diagram in Fig. 1 is made of a hand-fired boiler and it might be expected that the curves would show a much more regular aspect with mechanical stokers. That this is not the case is shown by Fig. 2 being a diagram of a 350-hp boiler with inclined type of mechanical stoker. The boiler was attended by three men and the curves plainly show how much the personal equation enters into the handling of even a boiler equipped with a mechanical stoker.

Brogan beginning at 7 a. m. brings the differential pressure quickly down to about 0.4 in. at 7.30 a. m. and practically maintains same at this height until 3 p. m.

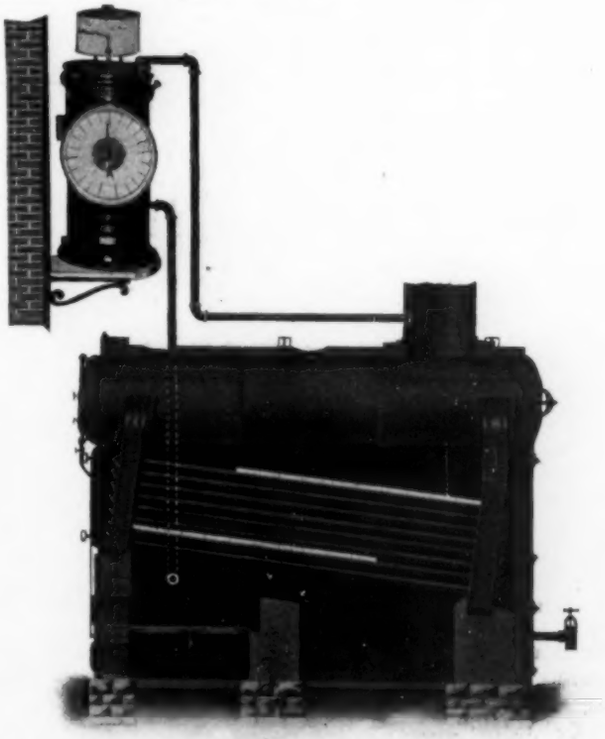


FIG. 3.—RECORDING VELOCITY GAUGE FOR BOILER PLANT.

At 3 p. m. Hahmese takes the job and right away gets in trouble. The differential pressure quickly increases and shows sudden drops at about 3.30, 4.50, 6.40, 7, etc. This is caused by the fireman closing the doors of the ashpit, which was the only means of regulation employed in this plant. From 6:40 to nearly 7 p. m., that is, for nearly 20 minutes, it was necessary for him to throttle the air supply in order to reduce the head of steam, although this was one of the periods that the peak-load occurs and the record is therefore a plain indication of waste.

At 11 p. m. Bradley goes on duty and no doubt the bad showing of his record between 11 p. m. and 12 p. m. is due to the unsatisfactory operation of his predecessor; from 12:30 a. m. to 7 a. m. his record shows up fairly good. Of course, with the increase of load more coal must be burned, which would in turn result in an increase of the differential pressure.

Therefore, a mere increase of the differential pressure is not necessarily an indication of waste, but when the curve shows so many sudden drops as is the case between 3:30 p. m. and 12 p. m., it most assuredly is. It shows that the combustion process has been accelerated too much, which is naturally coupled with waste of coal. With the further knowledge that the peak-load occurs between 7 a. m. and 10 a. m. and 5 p. m. and 9 p. m. and comparing the average differential pressures of these periods it is easy to deduct where waste has occurred.

Fig. 4 shows the construction of the apparatus, which is ingenious in its simplicity. It consists of a cylindrical vessel *g*, a cover *a*, which dips with its outer rim into a liquid contained within the annular space between vessel *g* and cylinder *h*. This liquid acts as a seal for the gas within vessel *g*. The working parts of the instrument consist of the bell *b*, to which is attached a float *c* guided upon a rod *d* and submerged in the operating fluid. Gas pressure is introduced under the bell through nozzle t_1 and above same through nozzle t_2, the differ-

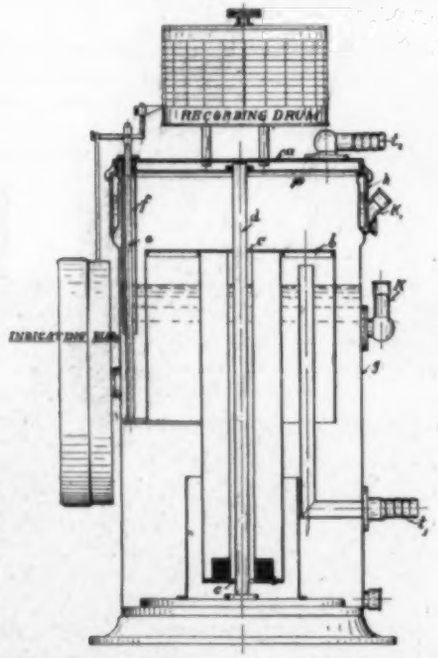


FIG. 4.—CONSTRUCTION OF RECORDING VELOCITY GAUGE.

ence causing the movements of the bell which are carried outwardly to the recording drum containing the clockwork of the instrument by means of rod *e* working through a tube *f* attached to the cover *a*.

The beauty of this arrangement is evident through the fact that the areas of bell and float stand in definite relation to the indications of the instrument. The standard construction is such that a differential pressure of 1 in. water represents a movement of 4 in. of the bell, and this being obtained without the use of magnifying levers justifies the claim of extreme sensitiveness and accuracy of indications for the instrument. In order to make the indications plainly visible to the fireman the rod *e* is further connected to a dial indicator magnifying the actual pressure 40 times. Workmanship of the instrument is in line with its other high-class features; in fact, the scientific principle of its operation, its construction and its usefulness merit a wide recognition for the instrument.

"Tycos"-Rochester is the title of a neat publication issued by the Taylor Instrument Companies, of Rochester, N. Y. The designated place of publication is given as the "Thermometer City," and the contents are devoted to an exposition of the variety of recording apparatus made by the company. The pamphlet is sent regularly to interested parties on request.

Repairs of Broken Castings by Reinforced Brazing.

BY W. G. SWANEY.

The importance of being able to repair a broken casting on the spot without loss of time is so evident that there is no need to discuss it further; the difficulties of this problem are well known.

Some four years ago certain men began experiments of brazing broken castings, and these proved so practical and successful that the Reinforced Brazing & Machine Company, of Pittsburg, Pa., was formed to carry on this business. The process as perfected is entirely original with this company, and by it the spelter is introduced directly into the pores of the iron on

FIG. 1.—6000-LB. HORIZONTAL PUNCH WITH HEAD BROKEN.

both sides of the brazed portion, thereby not only reinforcing the metal adjoining the fracture, but giving a firm hold on the body of the metal beyond the fracture back into the healthy strong metal.

The range of work which the company can undertake is very wide and covers all sizes of castings, from the smallest to the largest, this being evidenced both from the illustrations shown herewith and the fact that it has brazed successfully broken castings from a waffle iron up to a 27-ton engine bed. Many of these, too, have been of both a delicate and intricate character and necessitated great care to preserve the original lines of the

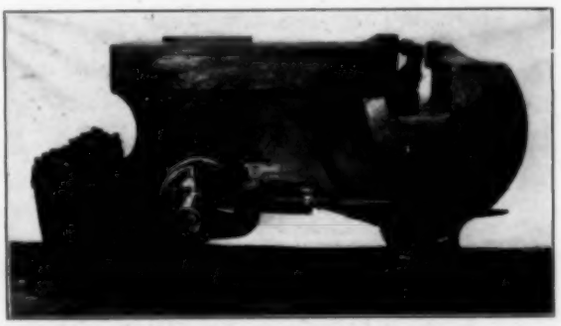


FIG. 2.—REPAIR OF FIG. 1.

casting, but in every case they have been put in as good a condition, and in many cases better, than prior to the break, and are serving their purpose to-day.

It often happens that the original casting was not strong enough for the purpose it served, and broke through weakness. In these cases not only does this company unite the fractured portions, but also introduces reinforcements of steel, thereby increasing the original strength of the casting and enabling it to hold up under its work.

The illustrations shown herewith are taken from a number of similar cases showing work which has been brazed and put back into service, and all of which without this treatment would have been consigned to the scrap pile, so that they give a convincing idea of the great benefit and value which the perfection of this process will be to the mechanical world.

There are many instances, however, to which the "reinforced brazing" process is not applicable, on account of the lightness of the pieces or the liability of warping or distorting the same while bringing them to a brazing heat. In such instances the oxygen-acetylene process is applied, and the results obtained have been highly satisfactory. To demonstrate this, the repair of automobile cylinders may be mentioned. This job is daily being made, and they are repaired so as to be quite as good as new without affecting the bore in any manner whatsoever. It is applicable to any style of castings up to 1½ in. in thickness.

Fig. 1 shows a 6000-lb. horizontal punch with head broken. Fig. 2 shows the same after being repaired.

Fig. 3 shows a Baldwin-Westinghouse mine-locomotive frame with the bumper broken through coupling and bumper broken from both side frames. Fig. 4 shows the repaired frame ready for service and entirely as good as new.

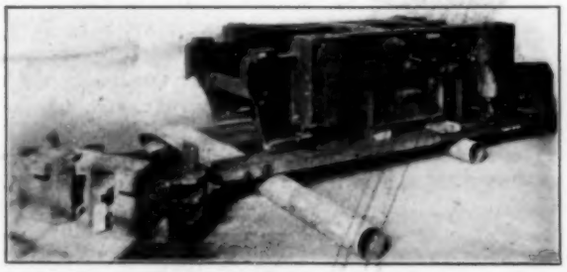


FIG. 3.—MINE LOCOMOTIVE WITH BUMPER BROKEN.

FIG. 4.—REPAIR OF FIG. 3.

FIG. 5.—BROKEN AUTOMOBILE CYLINDER.

FIG. 6.—REPAIR OF FIG. 5.

Figs. 5 and 6 show the results of oxygen-acetylene welding on Pope-Hartford automobile cylinders. These cylinders were cracked in the water jackets on all four sides, due to freezing, and were repaired without in any way injuring the bore.

The North Dakota School of Mines has recently installed a complete equipment for fuel and gas testing. A briquetting plant for lignite fuels and a gas-producer plant of the most approved type, together with a complete laboratory for fuel and gas analysis, comprise the installation.

Ozone Apparatus.

While the production of ozone has been studied for a long series of years by some of the most eminent chemical scientists, the industrial exploitation is comparatively of recent date. Nevertheless, in Europe, at least, there exists now a successful commercial ozone industry. The chief applications are, of course, purification of air and sterilization of water by means of ozone; both applications are being worked on a large scale, but ozone has also found application in breweries, tanneries, perfume factories, soap factories, lard factories, laundries, lace factories, distilleries, etc.

While this country has been somewhat slow in taking up the new development, considerable progress has recently been made along commercial lines. As the most recent instance, we notice the formation of the Standard Electro-Utilities Company, of Chicago, to give an impetus to a more satisfactory appreciation of the possibilities of ozone in this country.

This company owns the patents for the Vohr electric ozonizer, which is of very simple construction and which is stated to have a high efficiency. In order to accomplish an effective treatment of as large a volume of air as possible, the period of air contact in the Vohr ozonizer, through a rapidly revolving fan, which is one of the electrodes, is exceedingly brief. From 15,000 cu. ft. to 30,000 cu. ft. of air are treated per hour.

In the Vohr ozonizer the troublesome cleaning feature of some other types is eliminated. With no points to carbonize and no cleaning problem, the Vohr ozonizer is stated to remain practically permanently efficient. Further, one unit does the work of a number of separate units.

OZONIZER FAN.

The Standard Electro-Utilities Company have laboratory facilities, to which they invite the attention of those who may be interested in the subject of ozone. This company is equipped for any service which may require scientific data on this "coming field" of electrochemistry.

Electric Steel Refining.

The Crucible Steel Company of America has adopted the Heroult electric steel furnace for the production of highest grades of steel. A 5-ton furnace, to operate in conjunction with a 40-ton basic Wellman furnace, will first be installed at the Atha Steel Works in Harrison, N. J., and a duplicate of this is contemplated for the Park Steel Works in Pittsburgh. Even greater progress is reported from England. A number of large English steel works are making plans now to put up several large Heroult furnaces, three of which will have a capacity of 20 tons each.

Friedrich Krupp & Company, in Essen, are installing the Girod electric furnace for the production of the highest qualities of steel. It is understood that their contract calls for the installation of five furnaces each of 10 to 12 tons capacity, and that it is intended to operate them both with cold and molten charges.

A Scientific Abrasive Helpful.

Steel emery and crushed steel is, no doubt, known to some of our readers, but whether its use as it has developed in the last five years has been noticed by others than those who come in contact with it is doubtful.

Crushed steel and steel emery is a product made of crucible steel fractured into grains of various fineness and then tempered to the required hardness and toughness. These particles are very carefully graded, so that the grains are of the exact size.

This in itself is a remarkable development and took years to perfect.

Its effectiveness in abrading or grinding, particularly in valves that show wear or leakage in plants where shut-down or removal of parts means serious loss, is one of its many applications or uses. Many of the water works and practically all the railroad shops in the United States use it for valve grinding when two surfaces are to be faced together so as to form a steam or air-tight joint.

A very small quantity of steel emery is effective, and its grinding quality is so rapid that its value for work of this kind is easily appreciated.

These materials are used for all other applications of grinding and cutting where same is used loose or in bulk, not used with a binder. This is brought about from the fact that all the angles of the grains are sharp and distinctive and in use for grinding, cutting and sawing, when one edge becomes worn out it presents in its operation a new one, thereby avoiding at all times flat abrading or cutting sides.

It is used effectively in the making of slides and absolutely plane surfaces for scientific measurements and is used largely by the optical and lens makers.

The largest use for crushed steel is for the sawing and rubbing of all kinds of stone, marble, granite, etc., taking the place of sand at the very lowest cost of the latter.

This material has been manufactured for more than 20 years by the patentees and owners of the Pittsburgh Crushed Steel Company, Pittsburgh, Pa.

Filter-Tank Cyanide Process.

Among the many mechanical devices invented for the purpose of making ores more amenable to the cyanide process, the Holderman filter tank, of the Holderman Process Company, Salt Lake City, is worthy of some note. The basic idea of the Holderman process is to treat finely ground ore with cyanide solution, without previous separation of sand and slime, and to filter the gold-cyanide solution from the pulp without the use of filter presses or other expensive auxiliary apparatus. Rapidity of operation is effected by greatly increasing the leaching and filtering surface, and by the use of a simple agitator.

Each filter-tank is an oblong wooden or steel body about 10 ft. long, 6 ft. wide and 6 ft. deep. Fitting inside the tank and of about the same dimensions, is a large canvas filtering sack or basket. Space is maintained between the canvas and the walls of the tank by means of square slats nailed to the inside bottom and by V-shaped slats nailed to the sides and ends. The bottom of the tank slopes from back to front, having a pitch of 2 in. to the foot. Discharge gates are placed in the front wall, the bottoms of the openings being flush with the bottom of the tank. A drain pipe is set in one corner of the tank to carry off filtered solution. By this arrangement of the filtering sack the area of the filter medium is greatly increased.

This effect is still further augmented by the use of adjustable frame filters set at intervals across the tank. These occupy but little space and are made to communicate with the space between the large filter sack and the walls of the tank. The number of these filter leaves used in any tank depends on the treatment conditions and is increased or decreased according as greater or less leaching and filtering area is wanted. The frame of each leaf is of iron pipe enclosing a leaf of coarse matting, all being sewed over with the filter fabric.

Agitation may be used if found necessary and is accomplished by a simple device consisting of a revolving longitudinal shaft to which are fixed screw blades or paddles at intervals to correspond with the spaces between the filter frames.

For simple percolation three or more of the above-described tanks are arranged in stair-like succession, as shown in the accompanying illustration. The ore, crushed to pass through a 40-mesh, or finer, screen, is charged into the tank without separation of slimes from sands. If the charge be of dry ore the dissolving solution may be added by flooding the surface of the charge, in which case the fluid makes its way quickly through the exposed parts of the various filters until the liquid spaces between filter fabric and body of tank and within the frame filters are filled; or the solution may be introduced, to the same effect, through the solution-discharge pipe of the tank and be thus immediately communicated to every inch of filter fabric, providing an aggregate of percolating area co-extensive with that of the filtering area, plus the surface square measurement of the ore contained.

As every particle of ore is within a few inches of a fluid-filled surface, thorough percolation is certain and quick. Here is seen the effectiveness of side percolation as against that of percolation merely from above or below, for each moistened particle becomes suspended in the all-surrounding liquid, leaving the next free to the attack of the incoming flood, whereas in percolation from above or from below only, packing is certain and percolation out of the question when ore is slimy.

If the ore to be treated is crushed wet without cyanide, the excess of moisture may be quickly filtered off by turning the charge into the first tank, leaving the solution drain pipe open; or, what it better still, large square or oblong settling tanks fitted with the cross-frame filters may be used to receive the crushed product, in which case the recovered moisture may be pumped back to the crushing machinery or otherwise usefully disposed of, this arrangement proving of immense value where there is a scarcity of water. From such settling tanks the pulp drained thus of its surplus moisture may be sluiced down into the dissolving filter tank with the required strong cyanide solution.

Crushing with dissolvent solution is desirable, from many points of view, with certain ores. Where this method is adopted, the first tank may receive the pulp directly from the crushing machine or from tables, copper plates or other intermediary devices.

When sufficient time has elapsed for the dissolving of values contained in the ore under treatment, the drain pipe of the tank is opened and the gold-bearing solution flows in a continuous crystal stream to the zinc boxes. Supposing the tank to have been charged with equal weight of pulp and solution, 70 per cent to 84 per cent of the solution and necessarily an equal percentage of dissolved values will have been filtered off within from three to five hours, the exact percentage and the time within the stated limits being dependent upon the amount of slime in the charge. Thus, an all-slime pulp would give off 70 per cent to 75 per cent of the moisture within five hours, while an ore comparatively free from slime would give off 84 per cent or more within three hours.

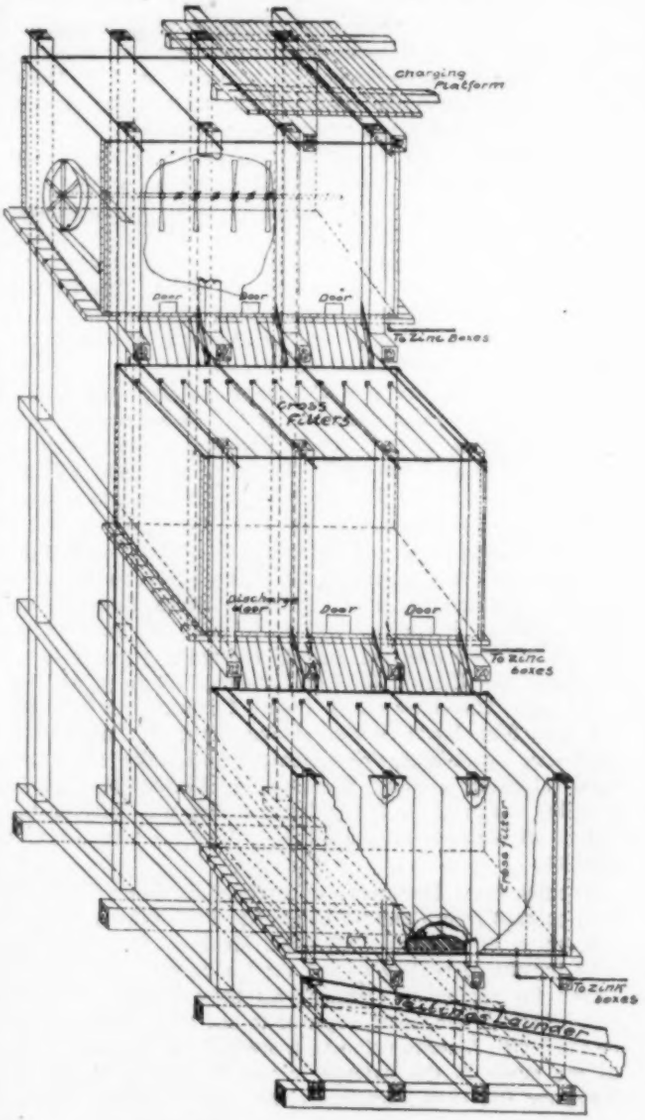
As soon as the desired percentage of moisture has been filtered off by the first tank, the front gates are opened, and by means of a hose supplied with weak solution or wash water, the partially treated pulp is sluiced into the succeeding tank. In this operation the merit of the inclined bottom of the tanks is seen, the discharge being completely effected with no more effort than is required to direct the hose. The discharging of the first tank effects the charging of the second, giving the pulp a thorough washing and aerating it in transit. This done, the first tank is left clean and ready to be recharged.

The time of the second tank is occupied in filtering, beginning with the inrush of sluiced matter from the first tank. Here may be seen to advantage one of the phenomenal features of the method, namely, this inrush of mud immediately transformed, as it were, and giving off or causing an outflow of a stream as clear as crystal, continuing so until 70 per cent to 84 per cent moisture is rendered through the filters and with it an equal amount of the dissolved values remaining from treatment in first tank.

The third tank, if used, bears the same relation that the second bears to the first, and is charged by the discharging and cleaning out of the second member, rendering in turn 70 per cent to 84 per cent of the dissolved values given to it. The pulp may then be finally disposed of either by sluicing through front discharge gates, where there is a sufficiency of water, or it may be dropped into cars through bottom discharge gates.

The per diem capacity of a set of three 10-ton tanks arranged and operated as described will depend in great part upon the time required to dissolve the values, and the time required to dissolve the values will depend mainly upon the fineness to which the ore is reduced. Having solved the mechanical difficulties of slime treatment, this method not only advocates fine grinding, but requires it, the additional cost of fine grinding being more than compensated for by higher extraction and less cost of treatment.

Given an all-slime ore, which without previous agitation with dissolvent solution, is charged into dissolving tanks as described, it will take from six to eight hours to dissolve the gold and filter off 70 per cent of the moisture; in other words, the dissolving tank, used as such in conjunction with its filtering function, will treat three charges per day, making one set of tanks equal to 30 tons daily capacity. But where the sole duty of the tanks is to separate dissolved values the daily capacity



FILTER TANK FOR CYANIDE PROCESS.

is nearly doubled, the tanks then being capable of treating five to six charges per day, or from 50 to 60 tons.

A pair of tanks, one agitating and the other non-agitating, each having a capacity of 10 tons of fine pulp or slime, can dispose of two charges in 24 hours. In a very slimy ore the entire operation can sometimes be carried out to the best advantage in a single agitator without using a supplementary tank, as the agitation would serve to keep the filter surfaces free from accumulation of slime. Considering the large filtering capacity of these tanks and their consequent ability to save by washing all that can be dissolved irrespective of slime contained, it is evident that high extraction is dependent on the dissolution of values, and to this end the ore may be ground as

fine as necessary. The Holderman system requires no slime separators or filter presses.

The Holderman Process Company has two experimental plants in Salt Lake City, one for small lots of 100 lb. per charge, or 300 lb. to 600 lb. per day, and the other for charges of 3000 lb., or 8 to 15 tons per day.

NOTES.

Gold in Country Rock.—The detection of minute traces of gold in country rock is almost a fruitless proceeding for the reason that the processes of assaying and the materials used are not of sufficient refinement. If one attempts to determine the gold by making many assays and parting all the buttons together, he concentrates the possible gold content of his litharge and thereby vitiates the result. If he attempts to make the determination on a single assay he can detect no gold.

Slag Bricks have been used rather extensively in the building operations of the Great Fitzroy copper mines, Mount Chalmers, Queensland. Offices, water tanks, retaining walls, and foundations have been made of them. The molds are made of two L-shaped cast-iron plates, of sufficient thickness to chill the slag without becoming overheated. Slag is cast from the slag pot and the molds are removed as soon as the slag has set. The bricks weigh about 80 lb. and have resisted a crushing stress of about 13 tons per square foot.

The **Bickford Firebrick Company,** having completed an addition to their plant, 300 ft. by 100 ft., will move their general office from Farmers' Bank Building, Pittsburgh, to the enlarged plant at Curwensville, Pa. The new plant will have a capacity of 100,000 brick per day and the increased output is to be available about July 15. The office moves May 1.

Sherardizing in the United States.—From the United States Sherardizing Company, of New Castle (the owners of the United States patents for Mr. Sherard Cowper Coles' "sherardizing" process of dry galvanizing), we learn that at the present time they are erecting sherardizing plants for the Westinghouse Electric & Manufacturing Company, of Pittsburgh; the Union Switch & Signal Company, at Swissvale; the John Finn Metal Works, of San Francisco, Cal.; and the American Three-Way Prism Company, of Chicago, Ill. The National Metal Molding Company, of Pittsburgh, have just installed a new sherardizing furnace that will increase their output of sherardized conduit pipe from 20 tons a day to 40 tons.

Pebbles from Denmark.—A carload of flint pebbles has been ordered from Denmark by the Rio Plata Mining Company for use in its mines in Chihuahua, Mexico. The pebbles are used for the regrinding of ore for the cyanide process. The reason for sending to Denmark for them is that the hardest flint pebbles in the world, superior to any that can be obtained on the North American continent, are to be found there. Most of the mines in the Arteaga mining district in Mexico use these, the Rio Plata Company alone, with an output of about 1,000,000 ounces of silver a year, requires a carload every five months.

The **Allis-Chalmers Company** has just closed the largest contract for mining and ore reduction machinery let since the panic, through its London office, with the Union Miniere du Haut Katanga, of Brussels, Belgium. This comprises every detail of the crushing, concentrating, and smelting equipment for a copper-producing plant of 900,000 tons yearly capacity, including power house and electrical equipment to be built near Lake Tanganyika in the Congo territory of Central Africa. This order, which covers one of the largest and most perfectly equipped mining plants in the world, was obtained in a wide competition because of the unique ability of an American company to supply all the machinery under a single contract.

The **Electric Controller and Manufacturing Company,** of Cleveland, Ohio, has recently issued a leaflet describing type G-2 controller, which has been designed primarily for 3½-hp. to 10-hp. motors. A few of the features claimed for this controller are accessibility, ruggedness, and long life. It has a cast grid resistance which will not burn out, and the heavy copper contacts are in a vertical plane, so that mill dust will not accumulate on them.

The **Denver Fire Clay Company,** Denver, Colo., has just issued the 1910 edition of its catalog of assayers' and chemists' supplies. This is by far the most elaborate and complete catalog this company has yet issued and contains in its 424 pages many illustrations and descriptions of new and improved forms of apparatus. In addition to the usual list of supplies for laboratories, assay offices, schools and colleges, there are the following new items: improved gas furnaces and burners, crushers and grinders, electrolytic assay apparatus, and revolving filter supports. Special laboratory furniture is a new feature of the catalog. The company has its main store and fireclay factory at Denver, Col., and a branch at Salt Lake City, Utah.

Edward Brown & Son, 311 Walnut Street, Philadelphia, manufacturers of indicating and recording instruments, have recently changed the firm name to *The Brown Instrument Company*. The officers remain exactly the same as before. In addition to the company's branch at Chicago, there has recently been opened an additional office in Pittsburg, in the Oliver Building, in charge of Mr. W. H. Gibb. This step has been necessary to give proper service to the company's growing business in that district.

Electric Steel in Mexico.—It is reported that the first "electric steel converter" (whatever that may mean) to be used in Mexico is to be installed in Mexico City at the Delicias rolling mills of Mr. Richard Honey. Preparations are also made to install several "modern furnaces" at the same plant. Bar iron and small iron rails comprise the output.

Oxy-Acetylene Welding.—It is announced that the Ohio Welding & Manufacturing Company, 282 West Sixth Street, Cincinnati, Ohio, is to act as a dealer for the Davis-Bournonville Company, of New York. They have installed a large demonstration plant, including not only the welding equipment, but an oxygen plant, and will carry out all kinds of repair work for which the oxy-acetylene process is suitable. This will include broken or cracked parts in cast iron, steel, aluminum, brass, copper, German silver, platinum, etc. Further parts cut too short can be lengthened, parts worn beyond use can have metal added and dressed down, etc. This company will also shortly open a demonstration and repair shop at 2121 East Second Street, Cleveland, Ohio.

Boston Belting Company, of Boston, Mass., announces that it has terminated the arrangements whereby the Jewell Belting Company, of Chicago, Ill., has been acting as its Western agent. The Boston Belting Company will open its own Western store at 177 Lake Street, Chicago, with Mr. M. S. Curwen in charge as manager of sales. The new store will carry an even more complete line of rubber belting, hose, packings, etc., than in the past, and will be able promptly to meet all orders and inquiries.

PERSONAL.

Mr. **R. L. Agassiz,** son of the late Alexander Agassiz, has been elected a director and vice-president of the Calumet & Hecla Mining Company.

Mr. **T. Walter Beam,** consulting engineer of Denver, was in New York early in April. He will visit the new mining camp of Porcupine, in Canada, in the interests of the International Smelting & Refining Company.

Mr. **D. W. Brunton,** consulting engineer of Denver, Colo., and president of the American Institute of Mining Engineers, met with a serious accident recently while on an automobile trip to inspect the Laramie tunnel in northern Colorado. While going down a steep grade the chauffeur lost control of

the machine and it plunged into the cañon below. One of the occupants of the car was killed, another suffered serious injuries and Mr. Brunton was badly injured. It is expected, however, that he will soon be able to resume his duties.

Mr. **H. C. Eastman**, of Denver, Colo., has been in New York for several weeks past.

Mr. **W. A. Hendryx**, manager of the Hendryx Cyanide Machinery Company, of Denver, Col., was in the East during April on a business trip to New York and Philadelphia.

Mr. **E. A. Le Sueur**, of Ottawa, Canada, was in New York last month.

Mr. **James McNaughton**, general manager of the Calumet & Hecla properties, who has been spending some time in Florida, has returned to Michigan.

Mr. **R. B. Martin**, formerly of Salt Lake City, has gone to Boston, where he will be in the employ of the American Chemical Company.

Mr. **C. W. Merrill**, metallurgical engineer of San Francisco, recently returned to the States after a two weeks' stay in Santa Barbara, Mexico.

Mr. **Louis D. Mills**, of San Francisco, is now in Mexico City, where he has charge of the Mexican territory in the interests of C. W. Merrill.

Mr. **Quincy A. Shaw** has been elected president of the Calumet & Hecla Mining Company, to succeed the late Alexander Agassiz.

Mr. **D. Sheedy**, of Denver, vice-president of the International Smelting & Refining Company, was in New York early in April.

OBITUARY.

The death of Mr. **Charles Loeb** occurred in New York City, Sunday, March 20, 1910. Mr. Loeb was president of the Zucker & Levett & Loeb Company, New York, and had long been intimately identified with the electroplating industry.

Dr. **Franklin R. Carpenter**, mining engineer and metallurgist, of Denver, Col., died on April 1, at the Auditorium Hotel, Chicago, where he was stricken with paralysis of the heart. Dr. Carpenter was 61 years of age and had spent the greater part of his life in the West, where he was successively identified with the educational, mining, and smelting interests of Colorado and South Dakota. In the Black Hills region of South Dakota he was well known on account of his early connection with the State School of Mines, and his later work in pyritic smelting at Deadwood. About 10 years ago he began operating pyritic plants in Colorado, the most notable of which were those at Golden and Florence. Dr. Carpenter was a member of many scientific bodies and a contributor to scientific literature on mining, geology and metallurgy.

Digest of Electrochemical U. S. Patents.

Prior to 1903.

Arranged according to subject matters and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

ELECTRIC FURNACES (*Continued*).

660,043, Oct. 16, 1900, Wilhelm Borchers, of Aachen, Germany.

Combined arc and resistance furnaces. The charge is heated by its own resistance; by a separate resistor; by independent arcs; or by using it as one or both poles of an arc. In one furnace the charge, for example, one for the production of calcium carbide, is fed from a hopper over an adjustably inclined hearth and is gradually heated by resistance, thence passing beneath an arc whereby it is fused and discharging into a receptacle beneath the end of the hearth. A tapered electrode serving as a resistor extends into the charge on the hearth, and the other vertical electrode depends over the end of the hearth. In a similar modified furnace, the hearth has a trough at its lower end to receive the molten product. In a second modification, the furnace chamber is vertical, and horizontal carbon electrodes are embedded in its side walls, making contact with the charge. Beneath the open lower end of the chamber is a rotating disk, serving as a hearth and cooled beneath by a spray of water. Electrodes project over the hearth at its sides and the heated material discharges over the edge of the hearth onto an inclined chute. In the third modification, a mixture of the charge and a binding material is continuously formed into a slab or bar which is forced over an adjustably inclined carbon hearth or contact block and beneath an arc, the molten product falling into a receptacle. The charge acts as a resistor and is supplied with increasing current as it approaches the arc. The furnace walls may be water-cooled and the electrodes may pass through water-cooled stuffing boxes.

662,537, Nov. 27, 1900, Hugo Koller, of Nuremberg, Germany.

The smelting chamber has vertical current-feed electrodes at its top and bottom, between which is a series of separate superposed carbon hoppers, serving as intermediate (bipolar) electrodes. Each hopper is supported by carbon blocks of fireproof insulating blocks. The hoppers are so placed that "several spheres of reaction arranged in series, but communicating one with the other, will be formed."

664,034, Dec. 18, 1900, Franz Heinrich Becker, of Weveling-hoven, Germany.

Arc type, for melting and refining glass. The charge descends from a hopper over an inclined undulating hearth, over which a series of arcs are sprung. It thence falls into one of several communicating compartments in a receiving and refining pot, heated by arcs from electrodes passing through the walls of the chamber. Continuous, alternating or polyphase current may be used.

665,704, Jan. 8, 1901, George S. Strong, of New York, N. Y.

Arc type. Improvement on furnace of patent No. 587,343, and especially designed for the manufacture of calcium carbide. The electrodes are constituted of the charge-mixture, a plastic mass, shaped and fed through opposed guides and conductors of hard carbon, held in water-cooled sockets. The mixture on its way to the arc zone passes through muffles heated externally by a mixture of oil or gas and air. The feeding is effected by rollers and screws, driven by electric motors, the speed of which is automatically controlled by the rate of consumption of the electrodes.

671,008, April 2, 1901, John Zimmermann and Isidore Sol Prenner, of Chicago, Ill.

Arc type, for producing calcium carbide (by the process of patent No. 675,646). The charge is a pasty mixture of lime, carbon and a binder, such as borax, graphite and iron or molasses, fed downward from a hopper and thence upward by a screw through a vertical tube. It thence discharges into an arc sprung between the ends of horizontal carbon electrodes, and the carbide falls downward into a receptacle below, two receptacles being filled alternately. The plastic mixture is preheated in the feed tube.

NEW BOOKS.

VAN NOSTRAND'S chemical annual. Edited by J. C. Olsen. Second edition revised and enlarged, 1909. 592 pages. Price, $2.50 net. New York: D. Van Nostrand Co.

SEXTON, A. HUMBOLDT. Fuel and Refractory Materials. New and revised edition. 364 pages, illustrated. Price, $2.50 net. New York: D. Van Nostrand Company.

ARMSTRONG, E. FRANKLAND. The simple carbohydrates and the glucosides. 121 pages. Price, $1.20 net. New York: Longmans, Green & Company.

Ripper, W. Heat engines (being a new edition of "Steam"). 332 pages, diagrams. Price, 90 cents net. New York: Longmans, Green & Company.

Maxim, Ja. L. The apprentices' course in experimental physics and mechanics for preliminary technical students and secondary school pupils; with numerous diagrams and recent examination questions. 126 pages. Price, 50 cents. New York: Longmans, Green & Company.

Warren, W. H. Engineering construction in steel and timber. Second edition. 487 pages, diagrams. Price, $5 net. New York: Longmans, Green & Company.

BOOK REVIEWS.

The Romance of Modern Chemistry. By **James C. Philip,** D. Sc., Ph. D. 12mo., 348 pages. Good index, 29 illustrations, 15 diagrams. Price, $1.50. Philadelphia: J. B. Lippincott Company.

The author is assistant professor of chemistry at the Imperial College of Science and Technology, London. He is to be heartily congratulated on his work. He presents the whole field of chemistry is a systematic, logical, highly accurate and fascinating manner. His facts are unimpeachable, theory carefully introduced, observations and conclusions keen and honest. The book is so simply written that almost any person who can read could understand and enjoy it; on the other hand, it is so accurate and comprehensive that every chemist would find pleasure and profit in it. It is truly an interesting book, and is most warmly recommended to our readers.

* * *

The Romance of Modern Manufacture. By **Charles R. Gibson.** 12mo., 320 pages. 28 illustrations, 16 diagrams. Price, $1.50. Philadelphia: J. B. Lippincott Company.

The book lives up to its name; sugar-coated phrases full of the marvelous; very readable and reasonably accurate. To us who know more about metallurgy than we do of cotton spinning, for instance, the latter seems more accurately described than the former. The book may be recommended as a good one for beginning a general scientific education or passing profitably some leisure hours; it should be especially attractive to boys.

* * *

The Copper Handbook. Vol. IX (1909). Compiled and published by **Horace J. Stevens,** Houghton, Mich. Octavo, cloth, pp. 1628. Price, $5.

The ninth annual volume of this work follows the same lines as did the preceding volumes, and brings statistics relative to copper and copper mines as nearly down to date as possible. Comparatively little new matter has been added to this volume, and most of the chapters remain as before, owing to the impossibility of properly revising the entire work in the short time available. The publisher plans to improve the conditions under which the work is carried on so that the entire volume will receive the attention it needs. The important chapters of the book have been thoroughly revised. These are the chapters devoted to the copper mines of the world, and the statistics of copper. The former lists and describes 7551 copper mines and mining companies, and the statistics cover every phase of the copper industry.

* * *

Mineral Resources of the United States. 1908. Vol. 1, Metallic Products (816 pages); Vol 2, Non-Metallic Products (899 pages). Washington, D. C.: U. S. Geological Survey.

These volumes constitute the twenty-fifth report on the mineral resources of the United States and comprise a census of the production, imports, exports, and other features of the metallic and non-metallic products of the country. As usual, the publication of the volumes has been anticipated by the advance publication of pamphlets comprising the various chapters of the volumes, so that the information contained is given to the public without waiting for the completion of the entire work.

The most notable general feature of the mineral production of the country for 1908 was the decline in value as compared with 1907. In 1905 and 1906 the total value of the domestic mineral production exceeded $1,500,000,000 and in 1907 the still greater sum of $2,000,000,000. In 1908, however, the effect of the industrial depression of the latter part of 1907 was reflected in the decreased value of total mineral production to about $1,596,000,000, or less than that for either 1905, 1906 or 1907. Iron, steel, manganese and silver showed a marked decline in production. Gold and copper increased, the output of the latter being the largest in the history of the industry. Lead recovered from the depression of 1907 more quickly than spelter, the latter experiencing a very hard year. The minor metals, as a rule, experienced a decrease in production.

Although the coal mining industry experienced the effects of the depression of 1907, nevertheless the production of coal for 1908 exceeded that of any year in our history except that of 1907. Petroleum experienced severe industrial reverses in 1908 due to floods and fires, but the output exceeded that of 1907. In the cement industry the production showed an increase of 1.3 per cent in quantity and a decrease of 20 per cent in value. The minor non-metallic mineral industries showed in a majority of cases decreases under the production for 1907.

* * *

A Study of Electrothermal and Electrolytic Industries. By **Edgar A. Ashcroft** (Statistics by **I. J. Moltkehansen**). Part I: Introductory. 8vo., 130 pages, 37 illustrations. Price, $2 net. New York: McGraw-Hill Book Company, 1909.

The whole work will be in three parts. Part I deals with the general chemical, physical, mathematical and engineering principles involved. Parts II and III will deal with the specific operations of electrochemistry and electrometallurgy in alphabetical order.

The present volume begins with an "Appreciation" concerning the historical side of the subject, which we fear will fail of being "appreciated" by the average American reader; it is too sketchy to be really instructive, and too philosophical to be *apropos:* his Pegasus flies too high. The chapter on the theory of electrochemistry is pleasant reading, accurate but not comprehensive. (On p. 12 Boyle's gas law is inverted, and on p. 13, 0.222 is printed for 0.0222; we regret to see decimals given without 0 before the decimal point.) The chapter on "Calculations" is lucid and accurate, but brief. The electrochemical equivalents of argon, helium, krypton, neon and xenon exhibit an amusing electrochemical *impasse,* with their valencies taken as zero.

The remaining two-thirds of the book contains very incisive views and practical observations upon the technical and commercial considerations involved in practical electrochemistry. The views expressed are in many cases far-sighted, and show a deep insight into and appreciation of the fundamental economics of the subject. The remarks upon cheap water-powers, future development of large industries, and their effects upon commercial geography and national developments are very well worth reading. The author states emphatically that "a great and important change in the world's industrial conditions is impending"—a change to be wrought by practical electrochemistry.

Finally, the philosophical author of "The World's Desires" (a very readable book, by the way) shows his appreciation of the liberal conditions for development in this country by the sentence: "No such restrictions exist in America, the land of freedom." Therefore, let the eagle (justifiably) scream, and may electrochemical industries flock to "the asylum for the oppressed."